FOR·THE·INCREASE·AND·DIFFVSION·OF·KNOWLEDGE·AMONG·MEN·

PER ORBEM

·SMITHSONIAN·INSTITVTION·WASHINGTON·1846·

A2/14/1980

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION

SHOWING THE OPERATIONS
EXPENDITURES, AND CONDITION OF THE INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1906

WASHINGTON
GOVERNMENT PRINTING OFFICE
1907

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1906.

SMITHSONIAN INSTITUTION,
Washington, May 13, 1907.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1906.

I have the honor to be, very respectfully, your obedient servant,

CHAS. D. WALCOTT,
Secretary.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1906.

SUBJECTS.

1. Proceedings of the Board of Regents for the sessions of December 5, 1905, and January 24, March 6, and May 16, 1906.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30 1906.

3. Annual report of the Acting Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1906, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1906.

CONTENTS.

REPORT OF THE ACTING SECRETARY.

GENERAL APPENDIX.

LIST OF PLATES.

THE SMITHSONIAN INSTITUTION.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

June 30, 1906.

THEODORE ROOSEVELT, President of the United States.
CHARLES W. FAIRBANKS, Vice-President of the United States.
MELVILLE W. FULLER, Chief Justice of the United States.
ELIHU ROOT, Secretary of State.
LESLIE M. SHAW, Secretary of the Treasury.
WILLIAM H. TAFT, Secretary of War.
WILLIAM H. MOODY, Attorney-General.
GEORGE B. CORTELYOU, Postmaster-General.
CHARLES J. BONAPARTE, Secretary of the Navy.
ETHAN ALLEN HITCHCOCK, Secretary of the Interior.
JAMES WILSON, Secretary of Agriculture.
VICTOR H. METCALF, Secretary of Commerce and Labor.

REGENTS OF THE INSTITUTION.

(List given on following page.)

OFFICERS OF THE INSTITUTION.

(Vacancy) *Secretary.*

RICHARD RATHBUN, *Assistant Secretary, in Charge U. S. National Museum (Acting Secretary).*

CYRUS ADLER, *Assistant Secretary, in Charge of Library and Exchange.*

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1906.

	Term expires.
The Chief Justice of the United States:	
MELVILLE W. FULLER, elected Chancellor and President of the Board January 9, 1889.	
The Vice-President of the United States:	
CHARLES W. FAIRBANKS, ex officio March 4, 1905	Mar. 3, 1909
United States Senators:	
SHELBY M. CULLOM (appointed March 24, 1885; March 28, 1889; December 18, 1895, and March 7, 1901)	Mar. 3, 1907
HENRY CABOT LODGE (appointed December 7, 1905)	Mar. 3, 1911
AUGUSTUS O. BACON (appointed December 7, 1905)	Mar. 3, 1907
Members of the House of Representatives:	
ROBERT R. HITT (appointed August 11, 1893; January 4, 1894; December 20, 1895; December 22, 1897; January 4, 1900; December 13, 1901; January 12, 1904, and December 13, 1905)	Dec. 25, 1907
ROBERT ADAMS, Jr. (appointed December 20, 1895; December 22, 1897; January 4, 1900; December 13, 1901; January 12, 1904, and December 13, 1905. Died June 1, 1906)	
HUGH A. DINSMORE (appointed January 4, 1900; December 13, 1901, and January 12, 1904)	Dec. 27, 1905
WILLIAM M. HOWARD (appointed December 13, 1905)	Dec. 25, 1907
JOHN DALZELL (appointed June 12, 1906)	Dec. 25, 1907

	Term expires.
Citizens of a State:	
JAMES B. ANGELL, of Michigan (appointed January 19, 1887; January 9, 1893; January 24, 1899, and January 23, 1905)	Jan. 23, 1911
ANDREW D. WHITE, of New York (appointed February 15, 1888; March 19, 1894; June 2, 1900, and April 23, 1906)	Apr. 23, 1912
RICHARD OLNEY, of Massachusetts (appointed January 24, 1900, and February 23, 1906)	Feb. 23, 1912
GEORGE GRAY, of Delaware (appointed January 14, 1901)	Jan. 14, 1907
Citizens of Washington City:	
JOHN B. HENDERSON (appointed January 26, 1892; January 24, 1898, and January 27, 1904)	Jan. 27, 1910
ALEXANDER GRAHAM BELL (appointed January 24, 1898, and January 27, 1904)	Jan. 27, 1910

Executive Committee of the Board of Regents.

JOHN B. HENDERSON, *Chairman.*

ALEXANDER GRAHAM BELL. ROBERT R. HITT.

PROCEEDINGS OF THE BOARD OF REGENTS FOR THE YEAR ENDING JUNE 30, 1906.

At a meeting held March 12, 1903, the Board of Regents adopted the following resolution:

Resolved, That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

In accordance with this resolution, the Board met at 10 o'clock a. m. on December 5, 1905, and on January 24 and March 6, 1906. A special meeting was also held on May 16, 1906.

REGULAR MEETING OF DECEMBER 5, 1905.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; Representative R. R. Hitt, Representative Robert Adams, jr., Representative Hugh A. Dinsmore, Dr. Andrew D. White, the Hon. John B. Henderson, the Hon. George Gray, and the Acting Secretary, Mr. Richard Rathbun.

The Acting Secretary announced that the Secretary was unable to be present on account of illness.

MINUTES OF PREVIOUS MEETING.

The minutes of the meeting held March 6, 1905, were read in abstract and approved.

DEATH OF SENATOR O. H. PLATT.

The Chancellor said: "It becomes my sad duty to bring to the attention of the Board a matter which is undoubtedly in the minds of us all—the departure of our friend and late colleague, Orville H. Platt. He died in the midst of his labors, cut like a diamond with its own dust. In view of his long and eminent career, and of the many years of faithful, intelligent, and useful service rendered this Institution, I suggest that we put upon our records a minute expressive of our sense of loss."

Judge Gray then offered the following resolutions, which were unanimously adopted:

Whereas the Board of Regents of the Smithsonian Institution is called upon to mourn the death, on April 21, 1905, of Orville Hitchcock Platt, a member of the Board since 1899;

Be it resolved, That the Regents give expression to their sense of loss in the

demise of a man of exemplary rectitude, who discharged all his duties with wisdom, fidelity and conscientious care; a statesman of the first rank whose services to his country are of enduring worth. This Board has lost a colleague whose interest in the affairs of the Institution was ever keen, and whose services were always helpful. At the meetings of the Board, on committees to which he was appointed, and in the Senate Chamber, his voice was always given with that combination of progressive thought and conservative judgment which so distinguished his character. In his death the nation has lost a wise statesman, the Institution a valued counsellor, and the members of the Board a cherished friend.

Resolved, That this resolution be entered as a part of the journal of the Board, and a copy thereof be transmitted to Mrs. Platt.

THE FREER ART COLLECTIONS.

The Chancellor brought before the Board the offer of Mr. Charles L. Freer, of Detroit, Michigan, to bequeath or make present conveyance of title to his art collections to the Smithsonian Institution or the United States Government, as indicated in his letter to the Secretary of December 27, 1904. The Acting Secretary read a letter from Mr. Freer, acknowledging the resolution adopted by the Board at its meeting on March 6, 1905.

After an extended discussion it was, on motion of Judge Gray:

Resolved, That in view of the difficulties concerning any action by the Regents in reference to the offer made by Mr. Freer, and of our high appreciation of the generosity exhibited by him, the Secretary be instructed to write Mr. Freer asking his permission to make public the correspondence between him and the Regents regarding his said offer.

The following resolution was also agreed to:

Whereas the special committee appointed to visit Detroit and examine the art collection of Mr. Freer reported that "it was mutually agreed that, at some early period during the next session of Congress and at the convenience of the Board of Regents of this Institution, Mr. Freer would visit Washington and exhibit such portions of his collection as might properly and fairly represent the whole;"

Resolved, That the Secretary be requested to provide a suitable place in the building of the Smithsonian Institution or the United States National Museum for the exhibit of such collections as Mr. Freer may desire to bring to Washington, and that he communicate with Mr. Freer to ascertain what time would be most convenient for the exhibit of a representative selection as agreed upon between Mr. Freer and the committee of the Board of Regents.

DEFALCATIONS OF W. W. KARR.

The Acting Secretary submitted to the Board, on behalf of the Secretary, a statement of the defalcations of W. W. Karr, for many years the accountant and disbursing agent of the Institution, involving a serious loss to its income. After remarks by Senator Hender-

son, chairman of the executive committee, and others, the following resolution was adopted:

Resolved, That the matter of the Karr defalcations be referred to the executive committee with a request that they will consider it fully and make report at the next meeting of the Board.

NEW BUILDING FOR THE NATIONAL MUSEUM.

The Acting Secretary reported progress in the construction of the new building for the National Museum. The first stone was laid on August 21, 1905, and the walls and piers of the basement were approaching completion. The steel girders for the main floor were at hand, and it was expected that the walls of another story would be finished before the end of the fiscal year.

ANNUAL MEETING OF JANUARY 24, 1906.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; Senator Henry Cabot Lodge, Senator A. O. Bacon, Representative Robert Adams, jr., Representative W. M. Howard, Dr. J. B. Angell, the Hon. Richard Olney, the Hon. George Gray, Dr. A. Graham Bell, and the Acting Secretary, Mr. Richard Rathbun.

APPOINTMENT OF REGENTS.

The Chancellor announced the appointment of Regents, as follows:

By the Vice President, on the part of the Senate, December 7, 1905: Senator Henry Cabot Lodge in place of Senator Orville H. Platt, deceased; and Senator A. O. Bacon to succeed Senator Francis M. Cockrell, whose term of service in the Senate had expired.

By the Speaker, on the part of the House of Representatives, December 13, 1905: Representatives R. R. Hitt and Robert Adams, jr., to succeed themselves, and Representative W. M. Howard to succeed Mr. Hugh A. Dinsmore, whose term as Representative had expired.

MINUTES OF PREVIOUS MEETING.

The minutes of the meeting held December 5, 1905, were read in abstract and approved.

THE SECRETARY'S ABSENCE.

The Chancellor read a letter from the Secretary explaining that illness would prevent his attendance at the meeting, and asking the indulgence of the Board for his absence from his post. The Secre-

tary stated that his last annual report to the Board had been completed prior to his illness and would be laid before the meeting, and that he was confident that the affairs of the Institution were well in hand and its work would go forward.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

On behalf of the executive committee Doctor Bell offered the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1907, be appropriated for the service of the Institution, to be expended by the Secretary, with the advice of the executive committee, with full discretion on the part of the Secretary as to items.

ANNUAL REPORT OF THE SECRETARY.

The Acting Secretary submitted the annual report of the Secretary to June 30, 1905, which was accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Doctor Bell submitted the annual report of the executive committee to June 30, 1905, which, on motion, was accepted, with the understanding that it might be brought up at the next meeting for adoption.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

The permanent committee reported, through Doctor Bell, as follows:

Hodgkins fund.—The case of Smith *v.* O'Donoghue has been set for hearing on the 13th of February next. This case, in which the Institution is interested as residuary legatee under the will of Mr. Hodgkins, involves the liability of the residual estate on a warranty deed of certain property in New York City conveyed by Mr. Hodgkins in May, 1871. It was decided in favor of the Institution in the appellate division, and the chances are considered excellent for success in the court of appeals.

Andrews will case.—The hearing upon the application of the executor to have the Andrews will interpreted was had in the New York supreme court, and a decision has been handed down establishing the right of the Andrews Institute for Girls to receive the legacy provided in the will, thus depriving the Smithsonian of the residual legacy of perhaps one and a half million dollars. Counsel of the Institution are of the opinion that though the decision in the lower court is unfavorable to the Institution the prospects of success in the appellate division are good. It is the intention to join with the heirs in appealing the case.

Avery bequest.—Offers have been received during the year from private parties for the purchase of several of the Avery properties, but as they were deemed inadequate, the proposals were not considered. An appraisement of these properties shows an estimated total valuation of $35,500.

Sprague and Reid bequests.—There have been no changes in the status of the Sprague and Reid bequests during the year.

On motion the report was accepted.

REPORT OF THE EXECUTIVE COMMITTEE ON THE DEFALCATIONS OF W. W. KARR.

Doctor Bell, on behalf of the executive committee, presented a report based upon their examination into the defalcations of W. W. Karr, in compliance with the resolution of the Board of December 5, 1905. The methods employed by the former accountant in abstracting funds and the amounts embezzled were fully set forth. The peculations consisted mainly in appropriating miscellaneous receipts derived from the sale of publications, repayments of moneys, etc., though approximately $4,000 had been taken from funds received for the International Catalogue of Scientific Literature and $7,400 from Government appropriations for the National Museum. The latter sum, however, was immediately repaid by the company by which Karr was bonded. The capital of the Institution, in view of the manner of its investment, could not be touched.

Immediately upon the discovery of the defalcation Karr was apprehended. Later he was indicted, pleaded guilty, and was sentenced to five years' imprisonment in the penitentiary.

The report concluded with a statement of the safeguards which had been adopted to prevent the further misappropriation of funds, and with a draft of the following resolution:

Resolved, That the executive committee be authorized to employ an expert accountant to act as clerk of the committee in connection with its examination of accounts.

The resolution was agreed to and the report accepted.

Doctor Bell expressed the opinion that the Institution was responsible for the amount abstracted by the accountant from the funds of the International Catalogue of Scientific Literature, which amount should have been forwarded to the London office by the Institution, in accordance with its agreement to act as the American representative for the collection and transmission of subscriptions. This view was accepted by the Board, and on motion of Judge Gray the following resolution was adopted:

Resolved, That the executive committee be instructed to make application to Congress, as they may see fit, for an appropriation to cover the amount collected by the Institution for the International Catalogue of Scientific Literature and embezzled by its former accountant.

THE FREER ART COLLECTIONS.

The Chancellor laid before the Board a letter from the President, urging the acceptance of the Freer collections, and inclosing a communication from Mr. Freer, dated December 15, 1905, reciting the terms and conditions of his offer as then made through him.

These letters are as follows:

THE WHITE HOUSE,
Washington, December 19, 1905.

To the Chief Justice of the United States, Chancellor of the Smithsonian Institution, and Member of the Board of Regents:

SIR: I herewith inclose a copy of a letter sent to me by Mr. Charles L. Freer offering to bequeath his art collections to the Smithsonian Institution or the United States Government, together with $500,000 in money to construct a suitable building; or if it is deemed preferable, to make a present conveyance of the title to such Institution or the Government and a bequest of the sum of $500,000 for the building. The offer is made upon certain terms and conditions which, in my judgment, are proper and reasonable.

It is impossible to speak in too high terms of the munificence shown by Mr. Freer in this offer; and it is one which the Government of the United States should at once close with as a matter of course. Mr. Freer's collection is literally priceless; it includes hundreds of the most remarkable pictures by the best known old masters of China and Japan. It also includes hundreds of pictures, studies, and etchings by certain notable American artists, those by Whistler alone being such as would make the whole collection of unique value—although the pictures by the Chinese and Japanese artists are of even greater worth and consequence. There are other art pieces which I need not mention. Any comptent critic can testify to the extraordinary value of the collection. I should suggest that either Doctor Sturgis Bigelow or Mr. John La Farge be sent to Detroit to examine the collection, if there is any question about it; although I assume that every member of the Board of Regents is familiar with its worth. The conditions which Mr. Freer imposes are in effect that nothing shall be added to or taken from the collection after his death, and that the collection shall be exhibited by itself in the building to be constructed for it without charge to the public; furthermore, that he shall have the right to make such additions to the collection as he may deem advisable, but not to take anything away from it after April next, the collections remaining in the possession of Mr. Freer until his death and then in the possession of his executors until the completion of the building. These conditions are, of course, eminently proper.

All that is asked of the Government or the Regents of the Smithsonian now is that they shall accept this magnificently generous offer. Nothing whatever else is demanded at present. When Mr. Freer's death occurs land will, of course, have to be allotted for the erection of the building—a building which will itself be a gift of great beauty to the Government—and when the building is completed and the collection installed therein, and not before, Congress will have to take some steps to provide the comparatively small sum necessary to take care of what will be a national asset of great value.

I need hardly say that there are any number of communities and of institutions which would be only too glad themselves to promise to erect such a building as that which Mr. Freer is going to erect, for the sake of getting this collection. The offer is one of the most generous that ever has been made to this Government, and the gift is literally beyond price. All that is now asked is

that we shall agree to accept on behalf of the nation the great benefit thus to be bestowed upon the nation.

I hope that the Regents of the Smithsonian will feel warranted to close with the offer; for they are the national guardians of such a collection. If in their wisdom they do not see their way to accept the gift, I shall then be obliged to take some other method of endeavoring to prevent the loss to the United States Government, and therefore to the people of the United States, of one of the most valuable collections which any private individual has ever given to any people.

Sincerely yours,

(Signed) THEODORE ROOSEVELT.

WASHINGTON, D. C., *December 15, 1905.*

To the PRESIDENT:

Permit me to repeat my offer to bequeath my art collections to the Smithsonian Institution or to the United States Government, and also the sum of five hundred thousand dollars in money for the purpose of constructing a suitable building in which to house them, upon the following terms and conditions:

First. The sum of five hundred thousand dollars shall be paid by my executors to the Regents of the Smithsonian Institution or the United States Government promptly after my decease, and shall be used forthwith for the construction of a fireproof building connected with the National Museum, the construction of which has been recently authorized, or reasonably near thereto.

Second. The interior of this building shall be arranged with special regard for the convenience of students and others desirous of an opportunity for uninterrupted study. A suitable space shall be provided in which the Peacock Room shall be reerected complete. The whole interior arrangement of the building shall be agreed upon between the Regents of the Smithsonian Institution and myself within a reasonable time after the acceptance of this offer.

Third. The collections, with such additions thereto as shall be made during my lifetime, shall be delivered by my executors to the Regents immediately after the building is constructed and ready to receive them.

Fourth. The collections and the building shall be cared for and maintained perpetually by the Smithsonian Institution or the United States Government at its own expense.

Fifth. No addition or deduction shall be made to the collections after my death, and nothing else shall ever be exhibited with them, or in the same building, nor shall the said collections, or any part thereof, be removed at any time from the said building except when necessary for the purpose of making repairs or renovations in the building.

Sixth. No charge shall ever be made for admission to the building or for the privilege of examining or studying the collections.

Seventh. The collections and building shall always bear my name in some modest and appropriate form.

In lieu of the foregoing offer, I am willing, upon the conditions above expressed, to make a present conveyance of the title to said collections to the Institution or the Government, and a bequest of the sum of five hundred thousand dollars for the building, provided:

1. The collections shall remain in my possession during my life, and in the possession of my executors after my death until the completion of the building.

2. I shall have the right to make such additions to the collections as may seem to me advisable or necessary for the improvement of the collections, or any of them.

3. On or before April next, I will file with the officials of the Smithsonian Institution or the United States Government a descriptive inventory of the objects belonging to the collections.

4. Both I and my executors shall be free from any liability on account of any loss in, or danger that may accrue to the collections while in my or their charge, even though such loss or injury shall occur by reason of my or their negligence, or the negligence of my or their servants, agents or employees.

The exact form of the bequest or gift, and the details for carrying it into execution, are legal questions that can be agreed upon by counsel representing the Institution or the Government and myself.

I am, with great respect, very sincerely yours.

CHARLES L. FREER.

This offer differed from that made directly to the Secretary of the Institution under date of December 27, 1904, in omitting the word "changes" in section 3 of the proposition to bequeath, leaving to Mr. Freer only the right to add to the collections, section 2 of the offer to make present conveyance being also modified to the same effect. Under the offer of present conveyance an additional clause, numbered 3, had been added, as follows: "On or before April next I will file with the officials of the Smithsonian Institution or the United States Government a descriptive inventory of the objects belonging to the collections."

After a discussion of the significance of these changes and of resolutions offered by Doctor Bell looking toward the acceptance of the offer, the following resolution was adopted:

The Board of Regents, recognizing the great value to the people of the United States of the art collection so generously offered by Mr. Charles L. Freer, of Detroit, Michigan,

Resolved, That the Board of Regents of the Smithsonian Institution do hereby accept the tender of Mr. Freer to make present conveyance to the Institution of the title to his art collection, and to bequeath to the Institution the sum of five hundred thousand dollars for the construction of a fireproof building in which to house it—under the terms as stated in his communication to the President of the United States dated December 15, 1905.

REQUEST OF BELL & CO. FOR REIMBURSEMENT IN CONNECTION WITH THE BARNETT FORGERIES.

Doctor Bell read a letter from Messrs. Bell & Co., bankers, requesting that the Institution submit an estimate to Congress for the sum of $525, with interest, to reimburse the bank in that amount, which had been paid on forged indorsements of Frank M. Barnett while an employee of the Bureau of American Ethnology. Doctor Bell said that the letter had been considered by the executive committee which had resolved to submit it to the Board of Regents with a recommendation that it be referred to the attorney of the Institution for examination and report. On motion, the letter was so referred.

REGULAR MEETING OF MARCH 6, 1906.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; the Vice-President, Hon. Charles W. Fairbanks; Senator Henry Cabot Lodge; Senator A. O. Bacon; Representative Robert Adams, jr.; Representative W. M. Howard; Dr. Andrew D. White; Dr. A. Graham Bell, and the Acting Secretary, Mr. Richard Rathbun.

DEATH OF SECRETARY LANGLEY.

The Chancellor announced the death of Secretary Langley, at Aiken, South Carolina, on February 27, 1906, and designated the Vice-President and Senator Lodge as a committee to draft a suitable minute to be spread upon the records and to be transmitted to the family of Mr. Langley. The following resolution was subsequently adopted by a rising vote:

Resolved, That the Board of Regents of the Smithsonian Institution express their profound sorrow at the death on February 27, 1906, of Samuel Pierpont Langley, Secretary of the Institution since 1887, and tender to the relatives of Mr. Langley their sincere sympathy in their bereavement;

That in the death of Mr. Langley this Institution has lost a distinguished, efficient and faithful executive officer, under whose administration the international influence of the parent Institution has been greatly increased, and by whose personal efforts two important branches of work have been added to its care—the National Zoological Park and the Astrophysical Observatory;

That the scientific world is indebted to Mr. Langley for the invention of important apparatus and instruments of precision, for numerous additions to knowledge, more especially for his epoch-making inventions in solar physics, and for his efforts in placing the important subject of aerial navigation upon a scientific basis;

That all who sought the truth and cultivated science, letters, and the fine arts, have lost through his death a coworker and a sympathizer;

That the executive committee be requested to arrange for a memorial meeting to be held in Washington;

That Dr. Andrew D. White be invited to prepare a suitable memorial which shall form a part of the records of this Board;

That the expenses of the funeral of Mr. Langley be provided for out of the income of the Institution.

APPOINTMENT OF REGENT.

The Chancellor announced the reappointment of Mr. Richard Olney as a Regent by joint resolution of Congress approved February 23, 1906.

MINUTES OF PREVIOUS MEETING.

The minutes of the annual meeting held January 24, 1906, were read in abstract and approved.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The report of the executive committee for the year ending June 30, 1905, presented and accepted at the annual meeting, was adopted.

REQUEST OF BELL & CO. FOR REIMBURSEMENT.

Doctor Bell, on behalf of the executive committee, reported that in accordance with the action of the Board at its last meeting the request of Bell & Co. had been submitted to the attorney for the Institution, who had expressed the opinion that the Institution was neither morally nor legally obligated. The matter was referred back to the committee for further inquiry and consideration, and Senator Bacon was designated to act with the committee.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Doctor Bell, on behalf of the executive committee, referring to the resolution adopted at the last meeting, authorizing the committee to apply to Congress for an appropriation to cover the amount collected for the International Catalogue by the Institution, and embezzled by the late accountant, reported that it was deemed inadvisable to make such application, but recommended that Congress be asked to appropriate funds for the continuance of the catalogue on behalf of the Government. He offered the following resolutions, which were separately adopted:

Resolved, That there be paid to the Central Bureau of the International Catalogue of Scientific Literature at London, from time to time as the funds permit, the sum embezzled by W. W. Karr from the subscriptions to this Catalogue collected by the Institution.

Resolved, That it is the sense of the Board of Regents of the Smithsonian Institution that the work for the International Catalogue of Scientific Literature be continued, and that application be made to Congress for a sufficient annual appropriation to enable this work to be carried on under the direction of the Institution.

RESOLUTIONS OF THE AERO CLUB.

The Acting Secretary read the following resolutions regarding the aerodromic work of the late Secretary, which had been adopted by the Aero Club of America on January 20, 1906:

Whereas our esteemed colleague, Dr. S. P. Langley, Secretary of the Smithsonian Institution, met with an accident in launching his aerodrome, thereby missing a decisive test of the capabilities of this man-carrying machine, built after his models, which flew successfully many times; and

Whereas, in that difficult experiment, he was entitled to fair judgment and distinguished consideration because of his important achievements in investigating the laws of dynamic flight, and in the construction of a variety of successful flying models: Therefore be it

Resolved, That the Aero Club of America, holding in high estimation the contributions of Doctor Langley to the science of aerial locomotion, hereby expresses to him its sincerest appreciation of his labors as a pioneer in this important and complex science; and

Be it further resolved, That a copy of these resolutions be sent to the Board of Regents of the Smithsonian Institution and to Doctor Langley.

ELECTION OF A SUCCESSOR TO THE LATE SECRETARY LANGLEY.

May 16, 1906, was fixed by the Board as the date for a special meeting for the election of a Secretary.

SPECIAL MEETING OF MAY 16, 1906.

Present: Mr. Chief Justice Fuller (Chancellor) in the chair; the Vice-President, Mr. Fairbanks, Senator S. M. Cullom, Senator Henry Cabot Lodge, Senator A. O. Bacon, Representative R. R. Hitt, Representative Robert Adams, jr., Representative W. M. Howard, Dr. J. B. Angell, Dr. Andrew D. White, the Hon. J. B. Henderson, the Hon. Richard Olney, the Hon. George Gray, and Dr. A. Graham Bell.

The Chancellor stated that the meeting had been called by the action of the Board at its last meeting for the purpose of electing a successor to Secretary Langley. The Board then went into executive session, Judge Gray acting as Secretary.

DONATION OF MR. S. P. LANGLEY'S MEDALS AND TOKENS.

The Chancellor read the following memorandum from the Acting Secretary:

I am sure you will consider it of interest to announce to the Board of Regents that the heirs of the late Secretary Langley have presented to the Smithsonian Institution all of the medals and other tokens received by Mr. Langley in recognition of his contributions to the advancement of knowledge. Among these are gold medals from the Royal Society of London, the Institute of France, the National Academy of Sciences, and the American Academy of Arts and Sciences.

It is proposed to assemble these, together with some of the earlier pieces of apparatus with which Mr. Langley began his memorable observations on the physics of the sun, in a case in the National Museum, alongside of those dedicated to the memory of Professor Henry and Professor Baird.

ELECTION OF A SECRETARY.

The question of the election of a Secretary was then taken up, and, after discussion, it was "moved by the Vice-President that the election of a Secretary be postponed to the next regular meeting of the Board." So voted.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1906.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and the disbursement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1906, and balances of previous appropriations.

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1906.

The permanent fund of the Institution and the sources from which it has been derived are as follows:

DEPOSITED IN THE TREASURY OF THE UNITED STATES.

Bequest of Smithson, 1846		$515, 169. 00
Residuary lagacy of Smithson, 1867		26, 210. 63
Deposit from savings of income, 1867		108, 620. 37
Bequest of James Hamilton, 1875	$1, 000. 00	
Accumulated interest on Hamilton fund, 1895	1, 000. 00	
		2, 000. 00
Bequest of Simeon Habel, 1880		500. 00
Deposits from proceeds of sale of bonds, 1881		51, 500. 00
Gift of Thomas G. Hodgkins, 1891		200, 000. 00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8, 000. 00
Deposit from savings of income, 1903		25, 000. 00
Total amount of fund in the United States Treasury		937, 000. 00

HELD AT THE SMITHSONIAN INSTITUTION.

Registered and guaranteed bonds of the West Shore Railroad Company, part of legacy of Thomas G. Hodgkins	42, 000. 00
Total permanent fund	979, 000. 00

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act of August 10, 1846, organizing the Institution, and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

By the final settlement of the estate of the late Thomas G. Hodgkins during the past year the Institution received, in May, 1906, the balance of the residuary legacy left by this benefactor. It amounted to $7,850, in the form of registered bonds of the United States, now recorded in the name of the Smithsonian Institution, and held subject to the order of the Board of Regents. Interest had accumulated on these bonds to the amount of $3,225.55, which sum was paid in cash and deposited in the United States Treasury to the credit of the current account of the Institution.

Statement of receipts and disbursements from July 1, 1905, to June 30, 1906.

RECEIPTS.

Cash on deposit in the United States Treasury July 1, 1905			$5,153.92
Interest on fund deposited in the United States Treasury to July 1, 1905	$28,110.00		
Interest on fund deposited in the United States Treasury to January 1, 1906	28,110.00		
		$56,220.00	
Interest on West Shore Railroad bonds to January 1, 1906		1,680.00	
Accumulated interest on Hodgkins residuary legacy		3,225.55	
Real-estate rentals, Avery bequest		440.41	
Repayments, cash from sale of publications, etc		6,096.43	
			67,662.39
Total receipts			72,816.31

DISBURSEMENTS.

Buildings, care and repairs		4,462.31	
Furniture and fixtures		368.87	
General expenses:			
Salaries	$15,615.28		
Meetings	699.20		
Stationery	568.80		
Postage and telegrams	279.09		
Freight	139.66		
Incidentals	3,316.17		
		20,618.20	
Library:			
Purchase of books, binding, etc	826.00		
Salaries	1,193.00		
		2,019.00	

Publications and their distribution:			
Contributions to knowledge	$73.06		
Reports	482.02		
Miscellaneous collections	5,094.90		
Publication supplies	58.37		
Salaries	6,319.00		
		$12,027.35	
Explorations and researches		1,054.66	
Hodgkins specific fund:			
Researches and publications		3,906.66	
International exchanges		2,110.78	
International Catalogue of Scientific Literature:			
Salaries	3,760.34		
Supplies	153.38		
		3,913.72	
Legal expenses		1,069.82	
Obituary expenses, Secretary Langley		1,080.81	
Bills payable		10,000.00	
			$62,632.18
Balance June 30, 1906, deposited with the United States Treasurer			10,184.13

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Institution, and all payments are made by checks signed by the Secretary.

Your committee also presents the following statements in regard to the appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution, based on expenditures by the disbursing agent and audited by the Auditor for the State and other Departments.

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1906, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For expenses of the system of international exchanges between the United States and foreign countries under the direction of the Smithsonian Institution, including salaris or compensation of all necessary employees and the purchase of necessary books and periodicals" (sundry civil act, March 3, 1905)	$28,800.00

DISBURSEMENTS.

Salaries or compensation:	
1 assistant secretary, at $225	$2,700.00
1 clerk, at $150	1,800.00
2 clerks, at $125	1,750.00

Salaries or compensations—Continued.

1 clerk, at $116.66	$1,399.92		
2 clerks, at $80	1,886.66		
1 clerk, at $70	835.34		
1 clerk, at $65	780.00		
1 stenographer, at $110 and $125	1,402.50		
1 carpenter, at $91	84.93		
1 workman, at $70	840.00		
1 packer, at $55	512.42		
1 skilled laborer, at $80	40.00		
1 skilled laborer, at $45 and $55	140.75		
1 messenger, at $30 and $35	387.50		
2 messenger boys, at $25	267.50		
1 messenger boy, at $20 and $25	267.50		
1 agent, at $66.66⅔	800.00		
1 agent, at $15	180.00		
1 agent, at $75	900.00		
Total salaries or compensation		$16,975.02	
General expenses:			
Books	76.15		
Boxes	1,319.00		
Freight, etc	8,503.60		
Furniture	14.05		
Postage	400.00		
Supplies, electricity, etc	299.03		
Stationery, etc	307.20		
		10,919.03	
Total disbursements			$27,894.05
Balance July 1, 1906, to meet outstanding liabilities			905.95

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1905, as per last report	$4,513.95

DISBURSEMENTS.

Salaries:			
1 agent, at $75	$450.00		
1 agent, at $66.66⅔	400.00		
1 agent, at $15	90.00		
Total salaries		$940.00	
General expenses:			
Freight, etc	2,676.49		
Boxes	442.50		
Furniture	29.50		
Lighting	30.94		
Miscellaneous supplies	104.35		
Stationery, books, printing, etc	290.11		
		3,573.89	
Total disbursements			4,513.89
Balance July 1, 1906			0.06

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1905, as per last report ---------- $10.08

Balance carried under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, $40,000, of which sum not exceeding $1,500 may be used for rent of building" (sundry civil act March 3, 1905) ---------- $40,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 chief, at $333.33	$3,999.96	
1 ethnologist, at $250	3,000.00	
1 ethnologist, at $200	2,400.00	
1 ethnologist, at $200	2,400.00	
1 ethnologist, at $133.33	1,599.96	
1 ethnologist, at $133.33	1,599.96	
2 ethnologists, at $125	3,000.00	
1 illustrator, at $166.67	2,000.04	
1 clerk, at $125	375.00	
1 archeologist, at $100	450.00	
1 editor, at $100	443.33	
1 editor and compiler, at $100	356.67	
1 head clerk, at $100	1,200.00	
2 clerks, at $100	2,400.00	
1 stenographer and typewriter, at $100	806.67	
1 typewriter, at $65	637.00	
1 typewriter, at $50	250.00	
1 skilled laborer, at $60	720.00	
1 messenger, at $55	660.00	
1 messenger, at $50	501.67	
1 laborer, at $45	540.00	
2 laborers, at $1.50 per day	120.75	
1 laborer, at $1.25 per day	37.50	
1 laborer, at $1 per day	1.50	
Total salaries or compensation		$29,500.01
General expenses:		
Books, binding, etc	332.68	
Drawings, maps, etc	179.95	
Electricity	300.71	
Freight, hauling, etc	218.52	
Furniture	219.71	
Manuscript	1,714.76	
Miscellaneous	191.36	

General expenses—Continued.

Postage, telephone, and telegraph	$132.70		
Rental	1,500.00		
Special services	1,753.25		
Specimens	605.00		
Stationery	530.44		
Supplies	494.09		
Travel and field expenses	1,704.54		
		$9,877.71	
Total disbursements			$39,377.72
Balance July 1, 1906, to meet outstanding liabilities			622.28

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1905, as per last report		$643.26

DISBURSEMENTS.

Freight	$59.57	
Furniture	10.07	
Lighting	83.40	
Miscellaneous	52.55	
Postage, telephone, and telegraph	67.43	
Rental	125.00	
Special services	26.69	
Stationery, books, etc	130.56	
Supplies	37.99	
Travel and field expenses	45.60	
Total disbursements		638.86
Balance July 1, 1906, to meet outstanding liabilities		4.40

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1905, as per last report	$75.70

DISBURSEMENTS.

Freight	7.67
Balance	68.03

Balance carried under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding 1,500 copies, repairs and alterations of buildings, and miscellaneous expenses, $15,000" (sundry civil act, March 3, 1905) $15,000.00

DISBURSEMENTS.

Salaries or compensation:			
1 aid, at $225	$2,700.00		
1 junior assistant, at $150	1,800.00		
1 clerk, at $125	125.00		
1 stenographer, at $116.66	1,351.31		
1 computer, at $83.33	477.76		
1 photographic assistant, at $70	210.00		
1 bolometric assistant, at $50	111.67		
1 messenger boy, at $30	360.00		
1 instrument maker, at $120 and $100	1,220.00		
1 skilled laborer, at $100	50.00		
1 carpenter, at $91	233.57		
1 skilled laborer, at $80	43.99		
1 fireman, at $60	704.00		
1 electrician, at $4 per day	24.00		
1 painter, at $3 per day	18.00		
1 helper, at $2 per day	14.00		
1 cleaner, at $1.25 per day	163.75		
1 cleaner, at $1 per day	11.00		
Total salaries or compensation		$9,618.05	
General expenses:			
Apparatus	1,178.80		
Books and binding	97.92		
Castings	28.40		
Drawings, tables, etc	175.00		
Electricity, gas, etc	209.15		
Freight	70.20		
Furniture	9.00		
Lumber	31.87		
Postage, telephone, and telegraph	7.92		
Stationery	58.31		
Supplies, chemicals, tools, etc	611.69		
Travel and field expenses	657.61		
		3,135.87	
Total disbursements			12,753.92
Balance July 1, 1906, to meet outstanding liabilities			2,246.08

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1905.

Balance July 1, 1905, as per last report $4,188.52

DISBURSEMENTS.

Salaries:	
1 bolometric assistant, at $50 per month	$25.00
General expenses:	
Apparatus	1,154.92
Building, repairs, etc	38.50
Freight	7.88
Lighting	90.00
Lumber	537.88
Miscellaneous supplies, chemicals, tools, etc	307.73

General expenses—Continued.

Postage, telephone, and telegraph	$3.46	
Special services	105.00	
Stationery, books, etc	298.80	
Travel, field expenses, etc	1,596.96	
Total disbursements		$4,166.13
Balance July 1, 1906, to meet outstanding liabilities		22.39

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1904.

Balance July 1, 1905, as per last report $33.02

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1906.

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, and all other necessary expenses, $180,000, of which sum $5,500 may be used for necessary drawings and illustrations for publications of the National Museum" (sundry civil act of Mar. 3, 1905) $180,000.00

DISBURSEMENTS.

Salaries or compensation	$163,002.81		
Special services	1,199.01		
Total salaries and services		$164,201.82	
Miscellaneous:			
Drawings and illustrations	1,991.98		
Freight and cartage	1,349.78		
Specimens	886.99		
Stationery	1,532.62		
Supplies	5,003.71		
Traveling expenses	874.40		
Total miscellaneous		11,639.48	
Total disbursements			175,841.30
Balance July 1, 1906, to meet outstanding liabilities			4,158.70

Analysis of disbursements for salaries or compensation.

Scientific and administrative staff:

1 assistant secretary, at $258.33	$3,099.96
1 administrative assistant, at $291.66	3,499.92
3 head curators, at $291.66	10,499.76
1 associate curator, at $200	2,400.00
2 curators, at $200	4,800.00

Scientific and administrative staff—Continued.

1 curator, at $100	$1,200.00	
4 assistant curators, at $150	7,200.00	
2 assistant curators, at $133.33	3,199.92	
2 assistant curators, at $125	1,500.00	
1 assistant curator, at $120	1,440.00	
2 assistant curators, at $116.66	2,799.84	
4 assistant curators, at $100	4,200.00	
1 second assistant curator, at $100	1,126.67	
1 assistant curator, at $83.33	999.96	
1 chief of division, at $200	2,400.00	
1 editor, at $167	2,004.00	
1 editorial assistant, at $133.33	1,033.30	
1 registrar, at $167	2,004.00	
1 disbursing agent, at $125	1,500.00	
1 assistant librarian, at $133.33	1,599.96	
2 aids, at $100	840.00	
2 aids, at $83.33	1,874.93	
2 aids, at $75	1,795.00	
3 aids, at $60	1,680.00	
3 aids, at $50	1,799.17	
1 aid, at $45	540.00	
1 assistant, at $3 per day	87.00	
		$67,123.39
Preparators:		
1 photographer, at $175	2,100.00	
1 photographer's assistant, at $50	250.00	
1 chief taxidermist, at $125	1,500.00	
1 taxidermist, at $100	1,200.00	
1 taxidermist, at $60	720.00	
1 taxidermist apprentice, at $25	299.58	
1 modeler, at $100	1,100.00	
1 osteologist, at $90	1,080.00	
1 preparator, at $125	1,500.00	
1 preparator, at $100	1,200.00	
2 preparators, at $90	2,019.00	
2 preparators, at $85	1,615.00	
1 preparator, at 50 cents per hour	516.00	
1 preparator, at $80	960.00	
1 preparator, at $70	833.00	
1 preparator, at $55	660.00	
1 preparator, at $45	540.00	
1 preparator, at $40	480.00	
1 preparator, at $25	300.00	
1 assistant preparator, at $45	538.50	
1 custodian, at $25	287.50	
1 classifier, at $100	1,200.00	
1 recorder, at $60	720.00	
2 cataloguers, at $60	870.00	
1 cataloguer, at $55	522.50	
3 cataloguers, at $50	335.00	
1 cataloguer, at $2 per day	18.00	
1 indexer, at $1.25 per day	15.63	
		23,379.71

Clerical staff:		
1 finance clerk, at $125	$1,500.00	
1 property clerk, at $90 and $100	1,135.00	
1 document clerk, at $55	660.00	
1 clerk, at $125	750.00	
1 clerk, at $115	1,380.00	
1 clerk, at $100	1,200.00	
7 clerks, at $75	6,297.50	
1 clerk, at $70	812.00	
4 clerks, at $60	2,040.00	
3 clerks, at $50	1,190.00	
1 clerk, at $35	420.00	
1 clerk and typewriter, at $75	900.00	
1 clerk and preparator, at $60	720.00	
1 stenographer, at $175	2,100.00	
1 stenographer, at $90	1,074.00	
1 stenographer, at $83.33	999.96	
1 stenographer and typewriter, at $90 and $100	1,180.00	
1 stenographer and typewriter, at $83.33	166.66	
1 stenographer and typewriter, at $75	75.00	
3 stenographers and typewriters, at $60	1,272.00	
5 stenographers and typewriters, at $50	969.16	
1 typewriter, at $85	1,000.17	
1 typewriter, at $75	900.00	
1 typewriter, at $60	712.00	
1 typewriter, at $50	193.33	
1 botanical assistant, at $75	215.00	
1 botanical clerk, at $75	117.50	
1 botanical clerk, at $1.50 per day	27.00	
3 messengers, at $40	800.00	
2 messengers, at $35	422.92	
1 messenger, at $30	60.00	
3 messengers, at $25	423.83	
5 messengers, at $20	447.50	
		$32,160.53
Buildings and labor:		
1 captain of watch, at $90	1,080.00	
2 lieutenants of watch, at $70	1,680.00	
1 watchman, at $65	780.00	
22 watchmen, at $60	15,044.00	
2 watchmen, at $55	550.00	
1 general foreman, at $122.50	1,184.17	
1 foreman, at $75	150.00	
1 carpenter, at $91	57.64	
1 workman, at $50	598.33	
1 skilled laborer, at $55	660.00	
5 skilled laborers, at $50	775.01	
1 skilled laborer, at $45	270.00	
3 skilled laborers, at $40	465.33	
1 skilled laborer, at $35	332.50	
9 skilled laborers, at $25	1,068.33	
3 skilled laborers, at $1.50 per day	605.25	

Buildings and labor—Continued.

1 skilled laborer, at $1 per day	$11.50	
3 classified laborers, at $47	1,585.40	
3 classified laborers, at $45	1,085.00	
1 classified laborer, at $40	280.00	
15 laborers, at $40	6,606.82	
1 laborer, at $35	420.00	
21 laborers, at $1.50 per day	891.69	
1 laborer, at $1.25 per day	6.25	
3 laborers, at $1 per day	132.75	
2 attendants, at $40	832.00	
1 attendant, at $1.25 per day	227.50	
10 cleaners, at $35	2,959.71	
		$40,339.18
Total salaries or compensation		163,002.81

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1905, as per last report	$6,645.34

DISBURSEMENTS.

Drawings and illustrations	$250.60	
Freight and cartage	812.28	
Salaries or compensation	6.67	
Special services	959.64	
Specimens	437.58	
Stationery	652.36	
Supplies	2,227.73	
Traveling expenses	727.18	
Total disbursements		6,074.04
Balance July 1, 1906, to meet outstanding liabilities		571.30

PRESERVATION OF COLLECTIONS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$198.99

DISBURSEMENTS.

Freight and cartage	$68.13	
Special services	120.00	
Total disbursements		188.13
Balance		10.86

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" (sundry civil act, March 3, 1905)	$22,500.00

DISBURSEMENTS.

Salaries or compensation	$11,563.09		
Special services	33.25		
Total salaries and services		$11,596.34	
Miscellaneous:			
Cases, storage	1,745.71		
Cloth, cotton, etc	343.71		
Drawers, trays, boxes	2,618.86		
Drawings	18.00		
Glass	168.80		
Glass aquarium	6.25		
Hardware	573.92		
Lumber	690.56		
Office furniture	1,103.05		
Paints, oils, brushes, etc	226.30		
Paper	24.00		
Rubber, leather, cork	336.80		
Slate	157.42		
Tools	181.00		
Travel	30.80		
Woodwork	21.50		
Total miscellaneous		8,246.68	
Total disbursements			19,843.02
Balance July 1, 1906, to meet outstanding liabilities			2,656.98

Analysis of disbursements for salaries or compensation.

1 superintendent, at $166.66	$999.96
1 clerk, at $110	1,320.00
1 shop foreman, at $90	1,080.00
4 carpenters, at $85	3,017.50
3 painters, at $75	1,105.63
1 painter, at $70	840.00
1 painter's helper, at $55	660.00
1 skilled laborer, at $100	550.00
1 skilled laborer, at $65	780.00
1 skilled laborer, at $55	550.00
1 workman, at $55	660.00
Total salaries or compensation	11,563.09

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance, July 1, 1905, as per last report		$2,769.99

DISBURSEMENTS.

Miscellaneous:		
Cloth, cotton, etc	$79.20	
Drawers, trays, boxes	728.75	
Frames, stands, etc	5.00	
Hardware	133.61	
Leather, rubber, cork	4.50	
Lumber	87.16	
Office and hall furniture	225.30	
Paints, oils, etc	13.85	
Slate	9.30	
Storage cases	863.25	
Structural steel work	98.84	
Tools, etc	432.55	
Total disbursements		2,681.31
Balance, July 1, 1906, to meet outstanding liabilities		88.68

FURNITURE AND FIXTURES, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$6.94

DISBURSEMENTS.

Disbursements	None.
Balance	6.94

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1906.

HEATING AND LIGHTING, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, March 3, 1905)		$18,000.00

DISBURSEMENTS.

Salaries or compensation	$8,267.34	
Special services	80.50	
Total salaries and services		$8,347.84
Miscellaneous:		
Advertising	13.95	
Coal and wood	4,812.70	
Electrical supplies	343.97	
Electricity	1,605.44	

Miscellaneous—Continued.

Gas	$563.20		
Heating supplies	377.73		
Rent of call boxes	110.00		
Telegrams	14.57		
Telephones	413.85		
Total miscellaneous		$8,255.41	
Total disbursements			$16,603.25
Balance July 1, 1906, to meet outstanding liabilities			1,396.75

Analysis of disbursements for salaries or compensation.

1 engineer, at $125	$1,500.00
1 telephone operator, at $70	840.00
3 telephone operators, at $1.50 per day	39.00
1 electrician, at $4 per day	100.00
1 fireman, at $60	720.00
1 blacksmith, at $60	720.00
1 steamfitter, at $80	913.34
1 plumber's assistant, at $65	780.00
1 skilled laborer, at $100	600.00
1 skilled laborer, at $80	920.00
1 skilled laborer, at $60	120.00
1 laborer, at $40 and $45	442.00
1 laborer, at $40 and $45	519.00
1 laborer, at $45	54.00
Total salaries or compensation	8,267.34

HEATING AND LIGHTING, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1905, as per last report	$1,469.40

DISBURSEMENTS.

Coal and wood	$5.90	
Electrical supplies	338.46	
Electricity	303.22	
Gas	41.20	
Heating supplies	335.55	
Rent call boxes	30.00	
Special services	113.38	
Telegrams	33.77	
Telephones	186.90	
Total disbursements		1,388.38
Balance July 1, 1906, to meet outstanding liabilities		81.02

HEATING AND LIGHTING, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance, July 1, 1905, as per last report	$54.48

DISBURSEMENTS.

Disbursements	None.
Balance	$54.48

Balance carried, under provisions of the Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

POSTAGE, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For postage stamps and foreign postal cards for the National Museum" (sundry civil act, March 3, 1905)	$500.00

DISBURSEMENTS.

For postage stamps and cards	500.00

PRINTING AND BINDING, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For the Smithsonian Institution, for printing labels and blanks, and for the 'Bulletins' and 'Proceedings of the National Museum,' the editions of which shall not be less than 3,000 copies, and binding in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library" (sundry civil act, March 3, 1905)	$25,000.00

DISBURSEMENTS.

Bulletins of the Museum	$7,413.42	
Proceedings of the Museum	12,930.57	
Contributions to National Herbarium	3,045.93	
Labels	217.39	
Blanks and circulars	382.29	
Public documents	73.72	
Binding	567.21	
Record books	145.40	
Total disbursements		24,775.93
Balance July 1, 1906, to meet outstanding liabilities		224.07

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, March 3, 1905)	$4,580.00

DISBURSEMENTS.

Rent of workshops:		
431 Ninth street SW., 12 months, at $166.66	$1,999.92	
217 Seventh street SW., 12 months, at $105	1,260.00	
309 and 313 Tenth street SW., 12 months, at $80	960.00	
915 Virginia avenue (rear), 12 months, at $30	360.00	
Total disbursements		4,579.92
Balance July 1, 1906		0.08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1906	$0.08

DISBURSEMENTS.

Disbursements	None.
Balance July 1, 1906	$0.08

RENT OF WORKSHOPS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$0.08

DISBURSEMENTS.

Disbursements	None.
Balance	$0.08

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1906.

BUILDING REPAIRS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, March 3, 1905)	$15,000.00

DISBURSEMENTS.

Salaries or compensation	$7,452.05		
Special services	48.00		
Total salaries and services		$7,500.05	
Miscellaneous:			
Asphalt	21.50		
Cement water table	230.00		
Cloth, etc	38.25		
Glass	30.65		
Hardware, tools	434.91		
Iron and steel doors, steps, etc	168.50		
Lime, plaster, sand, fireproof blocks	863.55		
Lumber	284.73		
Paints, oils, glue, brushes	221.59		
Plumbing material	215.59		
Repairs to roofs (by contract)	144.00		
Steel beams, angles, etc	40.90		
Woodwork	12.30		
Total miscellaneous		2,706.47	
Total disbursements			10,206.52
Balance July 1, 1906, to meet outstanding liabilities			4,793.48

Analysis of disbursements for salaries or compensation.

1 superintendent, at $166.66	$999.96
1 foreman, at $90	1,080.00
2 carpenters, at $85	1,232.50
5 painters, at $75	1,117.50
2 tinners, at $70	725.67
1 skilled laborer, at $70	81.67
1 classified laborer, at $60	720.00
1 rigger, at $60	600.00
1 messenger, at $40	120.00
1 laborer, at $47	141.00
1 laborer, at $40	480.00
4 laborers, at $1.50 per day	153.75
Total salaries or compensation	7,452.05

BUILDING REPAIRS, NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1905, as per last report	$1,800.90

DISBURSEMENTS.

Cement, mortar, marble, etc	$37.95	
Glass	5.70	
Hardware, tools, etc	259.20	
Lumber	12.97	
Paints, oils, etc	310.67	
Plumbing materials	238.32	
Repairs to roofs (by contract)	438.50	
Tile floors	190.00	
Total disbursements		1,493.31
Balance July 1, 1906, to meet outstanding liabilities		307.59

BUILDING REPAIRS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$53.34

DISBURSEMENTS.

Disbursements	None.
Balance	53.34

Balance carried under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

BOOKS, NATIONAL MUSEUM, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For purchase of books, pamphlets, and periodicals, for reference in the National Museum" (sundry civil act March 3, 1905)	$2,000.00

DISBURSEMENTS.

Books, pamphlets, and periodicals	$1,262.18
Balance July 1, 1906, to meet outstanding liabilities	737.82

BOOKS NATIONAL MUSEUM, 1905.

RECEIPTS.

Balance July 1, 1905, as per last report	$965.96

DISBURSEMENTS.

Books, pamphlets, and periodicals	905.69
Balance July 1, 1906, to meet outstanding liabilities	60.27

BOOKS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$18.32

DISBURSEMENTS.

Books, pamphlets, and periodicals	10.71
Balance	7.61

Balance carried under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

NATIONAL MUSEUM, TRANSPORTATION OF EXHIBITS ACQUIRED FROM THE LOUISIANA PURCHASE EXPOSITION.

RECEIPTS.

Balance July 1, 1905, as per last report	$5,235.12

DISBURSEMENTS.

Freight and cartage	4,063.79
Balance July 1, 1906, to meet outstanding liabilities	1,171.33

PURCHASE OF SPECIMENS, NATIONAL MUSEUM, 1904.

RECEIPTS.

Balance July 1, 1905, as per last report	$614.72

DISBURSEMENTS.

Disbursements	None.
Balance	$614.72

Balance carried under provisions of the Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1906.

NATIONAL ZOOLOGICAL PARK, 1906.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1906: "For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding 1,500 copies, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, $95,000" (sundry civil act, March 3, 1905) $95,000.00

DISBURSEMENTS.

Salaries or compensation:		
1 superintendent, at $275 per month	$3,300.00	
1 assistant superintendent, at $166.66 per month	1,999.92	
2 clerks, at $125 per month	3,000.00	
1 stenographer, at $83.33 per month	999.96	
1 messenger, at $50 and $60 per month	650.00	
1 messenger, at $45 per month	540.00	
1 messenger boy, at $1 per day	223.25	
1 photographer, at $70 per month	280.00	
1 head keeper, at $125 per month	1,500.00	
7 keepers, at $65 per month	5,421.00	
1 keeper, at $60 and $65 per month	750.00	
5 keepers, at $62.50 per month	3,750.00	
1 sergeant of watch, at $60 and $65 per month	750.00	
1 watchman, at $65 per month	780.00	
4 watchmen, at $60 per month	2,850.00	
1 attendant, at $22.50 per month	270.00	
1 attendant, at 75 cents per day	7.50	
Total salaries or compensation		$27,071.63
Miscellaneous:		
Buildings	4,307.47	
Building material	2,638.03	
Fencing, cage material	235.84	
Food for animals	14,424.60	
Freight	479.96	
Fuel	1,651.83	
Furniture	186.50	
Lumber	1,034.51	
Lighting	7.87	
Machinery, tools, etc	346.16	

Miscellaneous—Continued.			
Miscellaneous	$1,235.92		
Paints, oils, glass, etc	213.13		
Postage, telegraph, and telephone	215.03		
Purchase of animals	1,308.41		
Road material and grading	515.76		
Stationery, books, etc	256.97		
Surveying, plans, etc	340.00		
Travel and field expenses	220.40		
Trees, plants, etc	107.08		
Water supply, sewerage, etc	510.84		
Total miscellaneous		$30,236.31	
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:			
1 draftsman, at $100 per month	$130.00		
1 machinist, at $100 per month	1,200.00		
1 foreman, at $75 per month	900.00		
1 assistant blacksmith, at $60 per month	720.00		
1 workman, at $60 and $65 per month	750.00		
1 classified laborer, at $60 and $65 per month	748.00		
1 classified laborer, at $62.50 per month	750.00		
1 classified laborer, at $60 per month	720.00		
2 laborers, at $55 per month	1,320.00		
2 laborers, at $50 per month	1,188.75		
2 laborers, at $40 per month	960.00		
1 painter, at $75 per month	57.50		
1 painter, at $3 per day	55.50		
1 carpenter, at $3 per day and $75 per month	979.50		
3 carpenters, at $3 per day	216.00		
1 blacksmith, at $3 per day	493.50		
1 laborer, at $2.25 per day	689.62		
3 classified laborers, at $2 per day	1,981.00		
2 laborers, at $2 per day	782.00		
1 classified laborer, at $1.75 per day	624.75		
13 laborers, at $1.75 per day	6,725.70		
50 laborers, at $1.50 per day	8,841.52		
2 laborers, at $1 per day	156.50		
4 helpers, at 75 cents per day	352.71		
2 helpers, at 50 and 75 cents per day	376.02		
3 helpers, at 50 cents per day	67.26		
2 wagons and teams, at $3.50 per day	846.99		
2 horses and carts, at $1.75 per day	247.19		
Total wages of mechanics, etc		32,880.01	
Total disbursements			90,187.95
Balance July 1, 1906, to meet outstanding liabilities			4,812.05

NATIONAL ZOOLOGICAL PARK, 1905.

Balance July 1, 1905, as per last report		$11,157.73

DISBURSEMENTS.

Services of horse and cart	$1.75	
Buildings	5,745.61	
Building material	313.35	
Fencing, cage material, etc	81.19	
Food for animals	2,538.41	
Freight	520.21	
Lumber	272.32	
Machinery, tools, etc	198.88	
Miscellaneous	320.26	
Paints, oils, glass, etc	134.97	
Postage, telephone, and telegraph	64.22	
Purchase of animals	436.14	
Road material, grading, etc	74.30	
Stationery, books, printing, etc	86.53	
Trees, plants, etc	1.00	
Water supply, sewerage, etc	217.25	
Total disbursements		11,006.39
Balance July 1, 1906, to meet outstanding liabilities		151.34

NATIONAL ZOOLOGICAL PARK, 1904.

Balance July 1, 1905, as per last report		$1,376.99

DISBURSEMENTS.

Freight	$1.00	
Buildings	1,372.70	
Total disbursements		1,373.70
Balance		3.29

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1906.

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1906, appears from the foregoing statements to have been as follows:

SMITHSONIAN INSTITUTION.

From balance June 30, 1905	$5,153.92	
From receipts to June 30, 1906	67,662.39	
		$72,816.31

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International exchanges—Smithsonian Institution:		
From balance of 1904	$10.08	
From balance of 1905	4,513.95	
From appropriation for 1906	28,800.00	
		33,324.03

American Ethnology—Smithsonian Institution:		
From balance of 1904	$75.70	
From balance of 1905	643.26	
From appropriation for 1906	40,000.00	
		$40,718.96
Astrophysical Observatory—Smithsonian Institution:		
From balance of 1904	33.02	
From balance of 1905	4,188.52	
From appropriation for 1906	15,000.00	
		19,221.54
Preservation of collections—National Museum:		
From balance of 1904	198.99	
From balance of 1905	6,645.34	
From appropriation for 1906	180,000.00	
		186,844.33
Furniture and fixtures—National Museum:		
From balance of 1904	6.94	
From balance of 1905	2,769.99	
From appropriation for 1906	22,500.00	
		25,276.93
Heating and lighting—National Museum:		
From balance of 1904	54.48	
From balance of 1905	1,469.40	
From appropriation for 1906	18,000.00	
		19,523.88
Postage—National Museum:		
From appropriation for 1906		500.00
Printing and binding—National Museum:		
From appropriation for 1906		25,000.00
Rent of workshops—National Museum:		
From balance of 1904	.08	
From balance of 1905	.08	
From appropriation for 1906	4,580.00	
		4,580.16
Building repairs—National Museum:		
From balance of 1904	53.34	
From balance of 1905	1,800.90	
From appropriation for 1906	15,000.00	
		16,854.24
Books—National Museum:		
From balance of 1904	18.32	
From balance of 1905	965.96	
From appropriation for 1906	2,000.00	
		2,984.28
Transportation of exhibits acquired from the Louisiana Purchase Exposition—National Museum:		
From balance of appropriation		5,235.12
Purchase of specimens—National Museum:		
From balance of 1904		614.72
National Zoological Park:		
From balance of 1904	$1,376.99	
From balance of 1905	11,157.73	
From appropriation for 1906	95,000.00	
		107,534.72

SUMMARY.

Smithsonian Institution		$72,816.31
International Exchanges		33,324.03
American Ethnology		40,718.96
Astrophysical Observatory		19,221.54
National Museum:		
Preservation of collections	$186,844.33	
Furniture and fixtures	25,276.93	
Heating and lighting	19,523.88	
Postage	500.00	
Printing and binding	25,000.00	
Rent of workshops	4,580.16	
Building repairs	16,854.24	
Books	2,984.28	
Transportation of exhibits acquired from Louisiana Purchase Exposition	5,235.12	
Purchase of specimens	614.72	
		287,413.66
National Zoological Park		107,534.72
		561,029.22

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1906, each of which bears the approval of the Secretary or, in his absence, of the Acting Secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution.

The books and vouchers have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use during the year ending June 30, 1907.

Balance July 1, 1906		$10,184.13
Interest due and receivable July 1, 1906	$28,110.00	
Interest due and and receivable January 1, 1907	28,110.00	
Interest, West Shore Railroad bonds, due July 1, 1906	840.00	
Interest, West Shore Railroad bonds, due January 1, 1907	840.00	
		57,900.00
Total available for year ending June 30, 1907		68,084.13

Respectfully submitted.

J. B. Henderson, *Chairman*,
Alexander Graham Bell,
Executive Committee.

Washington, D. C., *January 7, 1907.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, ETC.

[Continued from previous reports.]

[Fifty-ninth Congress, first session.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution of the class other than members of Congress shall be filled by the reappointment of Richard Olney, a citizen of Massachusetts. (Approved February 23, 1906; Statutes, XXXIV, 822.)

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution of the class other than members of Congress shall be filled by the reappointment of Andrew D. White, a citizen of New York, whose term expires June second, nineteen hundred and six. (Approved April 23, 1906; Statutes, XXXIV, 827, 828.)

SMITHSONIAN DEPOSIT [LIBRARY OF CONGRESS].—For custodian, one thousand five hundred dollars; assistant, one thousand two hundred dollars; messenger, seven hundred and twenty dollars; messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Approved June 22, 1906; Statutes, XXXIV, 398.)

RUIN OF CASA GRANDE, ARIZONA.—For protection of Casa Grande Ruin, in Pinal County, near Florence, Arizona, and for excavation on the reservation, to be expended under the supervision of the Secretary of the Smithsonian Institution, three thousand dollars. (Approved June 30, 1906; Statutes, XXXIV, 729.)

PRINTING AND BINDING.—For the Smithsonian Institution, for printing and binding the Annual Reports of the Board of Regents, with general appendixes, ten thousand dollars; under the Smithsonian Institution, for the Annual Reports of the National Museum, with general appendixes, and for the Annual Report of the American Historical Association, and for printing labels and blanks, and for the Bulletins and Proceedings of the National Museum, the editions

of which shall not exceed four thousand copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, thirty-nine thousand dollars; for the Annual Reports and Bulletins of the Bureau of American Ethnology, twenty-one thousand dollars; in all, seventy thousand dollars. (Approved June 30, 1906; Statutes, XXXIV, 760.)

SMITHSONIAN GROUNDS: For improvement, care, and maintenance of Smithsonian grounds, three thousand dollars.

For resurfacing asphalt roadways in the Smithsonian grounds, five thousand dollars. (Approved June 30, 1906; Statutes, XXXIV, 733.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, twenty-eight thousand eight hundred dollars. (Approved June 30, 1906; Statutes, XXXIV, 704.)

NAVAL OBSERVATORY: For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Approved June 22, 1906; Statutes, XXXIV, 425.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians and the natives of Hawaii under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved June 30, 1906; Statutes, XXXIV, 704.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alterations of buildings and miscellaneous expenses, fourteen thousand dollars. (Approved June 30, 1906; Statutes, XXXIV, 704.)

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other necessary incidental expenses, five thousand dollars, the same to be expended under the direction of the Secretary of the Smithsonian Institution (Approved June 30, 1906; Statutes, XXXIV, 704.)

NATIONAL MUSEUM.

For continuing the construction of the building for the National Museum, and for each and every purpose connected with the same, five hundred thousand dollars.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty thousand dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, and all other necessary expenses, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand five hundred and eighty dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars. (Approved June 30, 1906; Statutes, XXXIV, 704.)

For preservation of collections, National Museum, twenty-six dollars and thirty cents. (Approved June 30, 1906; Statutes, XXXIV, 667.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and other-

wise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, including purchase, maintenance, and driving of horses and vehicles required for official purposes, ninety-five thousand dollars; one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Approved June 30, 1906; Statutes, XXXIV, 704, 705.)

JAMESTOWN EXPOSITION.

That there shall be exhibited at the Jamestown Exposition by the Government of the United States from the Smithsonian Institution, the National Museum, and the Library of Congress such articles and materials of an historical nature as will serve to impart a knowledge of our colonial and national history; and such Government exhibit shall also include an exhibit from the War and Navy Departments, the Life-Saving Service, the Revenue-Cutter Service, the Army, the Navy, the Light-House Service, the Bureau of Fisheries, and an exhibit from the Island of Porto Rico. And the Bureau of American Republics is hereby invited to make an exhibit illustrative of the resources and international relations of the American Republics, and space in any of the United States Government exhibit buildings shall be provided for that purpose. The Jamestown Tercentennial Commission, created by an act of Congress, approved March third, nineteen hundred and five, shall, in addition to the authority and duties conferred and imposed by said act, be authorized and empowered and it shall be their duty to select, prepare, transport, and arrange for the exhibition and return of the Government exhibits herein authorized. In addition to the articles and materials which the said Jamestown Tercentennial Commission may select for exhibition as aforesaid, the President of the United States may in his discretion designate other and additional articles and materials.

The officers and employees of the Government who may be appointed by the Jamestown Tercentennial Commission to carry out the provisions of this section and any officers and employees of the Government who may be detailed to assist them, including the officers of the Army and Navy, shall receive no compensation in addition to their regular salaries, but they shall be allowed their actual and necessary traveling expenses, together with a per diem in lieu of subsistence not to exceed four dollars. The officers of the Army and Navy

shall receive said allowance in lieu of subsistence and mileage not allowed by law and the Secretary of War and the Secretary of the Navy may in their discretion detail retired Army and Navy officers for such duty. Any provision of law which may prohibit the detail of persons in the employ of the United States to other service than that which they customarily perform shall not apply to persons detailed to duty in connection with said Jamestown Tercentennial Exposition. And to carry out in full all of the provisions of this section not herein otherwise specifically appropriated for, the sum of two hundred thousand dollars or so much thereof as may be necessary is hereby appropriated out of any moneys in the Treasury not otherwise appropriated, the same to be expended in accordance with law and under such rules and regulations as the said Jamestown Tercentennial Commission may prescribe.

That the Secretary of the Treasury shall cause suitable buildings to be erected on the site of the said Jamestown Tercentennial Exposition for said Government exhibit, including a suitable building for the exhibit of the United States Life-Saving Service; a fisheries building, including an aquarium; also a building for use as a place of rendezvous for the soldiers and sailors of the United States Navy and Army and of the foreign navies and armies participating in said celebration; also a building for use as a place of rendezvous for the commissioned naval and army officers participating in said celebration; also the preparation of the grounds for, the approaches thereto, and the lighting of all of said buildings. Said buildings shall be erected, as far as practicable, on the colonial style of architecture from plans prepared by the supervising architect of the Treasury, to be approved by the Secretary of the Treasury; and the Secretary of the Treasury is hereby directed to contract for said buildings in the same manner and under the same regulations as for other public buildings of the United States: *Provided*, That the aggregate cost of all of said buildings, including the preparation of grounds, approaches, and lighting, shall in no event exceed the sum of three hundred and fifty thousand dollars, which sum is hereby appropriated out of any moneys in the Treasury not otherwise appropriated. (Approved June 30, 1906; Statutes, XXXIV, 764, 765.)

REPORT

OF

RICHARD RATHBUN,

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE

YEAR ENDING JUNE 30, 1906.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: It is with profound sorrow that I record the death at Aiken, S. C., on February 27, 1906, of Samuel Pierpont Langley, Secretary of the Institution since 1887.

This is not the place to give an adequate review of the work of Mr. Langley as a man of science, or to recall his contributions to the progress of thought and to the upbuilding of the various scientific institutions with which he was connected.

I may be permitted, however, to express here my sense of bereavement in the passing away of a man whose friendship and personal and official confidence I was privileged to enjoy. Although connected with the Museum and the Institution in one capacity or another for more than thirty years, my close relations with the late Secretary did not begin until 1896. Within this decade I learned to know him as a man of the most profound intellect, an acknowledged master in that branch of astronomy which he had virtually made his own, and a pioneer in the difficult subject of mechanical flight. In his younger years he set himself to determine the nature and composition of the sun, and the properties of heat and light in their relation to life upon this planet. Later he attacked that fascinating problem, the maintenance and progress in the air of bodies many fold heavier than the medium through which they move.

That he should have investigated these two large difficult subjects was but typical of his most marked intellectual characteristic, which required that he knock incessantly upon the doors which were closed to others. He was equally, if not professionally, concerned with all

the difficulties which had presented themselves to the human intellect from the abstractions of the mathematician and the metaphysician to the mysteries of the theologian and the secrets of lost civilizations.

But this great man also lived upon the earth. In his youth and earlier manhood he had a business training and a business career, and he carried to the verge of the grave most scrupulously exact business methods. His theory of administration lay mainly in selecting men whom he could trust, and when he found that this trust was justified, in giving them his unbounded confidence. A man of the world, he yet retained the simplicity and rigid straightforwardness of the Puritan character, and though the arts of flattery were unknown to him, he bound to himself with indissoluble ties of affection, respect, and loyalty those who had the opportunity of coming closely in contact with him.

With this Institution he had completely merged his life; not even his favorite scientific pursuits weighed where the interests of the Institution were concerned; in season and out of season it was the object of his constant care. To it he added two new and important activities, the Astrophysical Observatory and the National Zoological Park. It was during his administration that the Smithson fund received its only considerable additions since the original gift, and that the new building for the National Museum was authorized by Congress.

The elegance of his style in writing and the clearness of his presentation, no matter what the subject might be, greatly enhanced the Institution's reputation both here and abroad. Hardly any other American man of science so frequently met the learned men of the Old World or received so many distinctions from the academies and universities and societies of Great Britain and the Continent.

He was not by any means solely devoted to the natural or physical sciences. The breadth of his knowledge of the things that make for culture, and especially his interest in the fine arts were almost equal to his devotion to science, and his wide knowledge of history, though confined to no one country, was more especially directed to France, with whose annals and memoirs his acquaintance was almost that of an expert. His literary sense, not surpassed by even the most cultivated of men, took the double direction of an enjoyment of all that was good in the best of literature, and an attempt to produce writing on scientific subjects which should be clear and intelligible to the man of ordinary education, and sometimes even to the child.

Many of these personal characteristics were reflected in the conduct of the Institution during his incumbency. The Smithsonian Report was made more popular in the best sense, conveying exact

information as to the advancement of science and the progress of knowledge to all who have an intelligent desire to keep themselves abreast of the world's thought.

The fine arts, which were provided for in the original law of the Institution, and which formed the object of its care at the beginning, had made but little progress for many years, because of the pressure of other subjects. He revived interest in this field in the early years of his administration and his action in this regard was more than justified by the noteworthy developments in the department of fine arts here in the past few years, developments which were slowly taking shape just as his life was drawing to a close.

In the passing away of this distinguished man of science, broad minded, cultivated, this Institution and the world at large lose a great leader, and the writer of these lines an inspiring guide and a sincere friend.

Out of respect to his memory the flags on the buildings of the Institution were carried at half mast until after the interment of his remains at Boston, on March 3. The offices of the Institution were closed on March 1, on which day the remains arrived in Washington, and on March 2, the day of the funeral services here. On the latter day business was also suspended in the offices of the National Museum, International Exchanges, Bureau of American Ethnology, National Zoological Park, and Astrophysical Observatory, and during the hours of the funeral services the exhibition halls were closed to the public.

A formal announcement of the death of Secretary Langley was sent to the foreign correspondents of the Institution, and many acknowledgments have been received, expressing regret at the loss which the world of science and the Institution have sustained.

In consequence of this sad event, it becomes my duty as Acting Secretary to submit a report showing the operations of the Institution during the year ending June 30, 1906, including the work placed under its direction by Congress in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, and the Astrophysical Observatory.

In the body of this report there is given a general account of the affairs of the Institution and its bureaus, while the appendix presents more detailed statements by those in direct charge of the different branches of the work. Independently of this, the operations of the National Museum and of the Bureau of American Ethnology are fully treated in separate volumes. The scientific work of the Astrophysical Observatory is recorded in occasional publications.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an Establishment. Its statutory members are "the President, the Vice-President, the Chief Justice, and the heads of Executive Departments."

As organized on June 30, 1906, the Establishment consisted of the following ex officio members:

Theodore Roosevelt, *President of the United States.*
Charles W. Fairbanks, *Vice-President of the United States.*
Melville W. Fuller, *Chief Justice of the United States.*
Elihu Root, *Secretary of State.*
Leslie M. Shaw, *Secretary of the Treasury.*
William H. Taft, *Secretary of War.*
William H. Moody, *Attorney-General.*
George B. Cortelyou, *Postmaster-General.*
Charles J. Bonaparte, *Secretary of the Navy.*
Ethan Allen Hitchcock, *Secretary of the Interior.*
James Wilson, *Secretary of Agriculture.*
Victor H. Metcalf, *Secretary of Commerce and Labor.*

THE BOARD OF REGENTS.

The Board of Regents consists of the Vice-President and the Chief Justice of the United States as ex officio members, three members of the Senate, three members of the House of Representatives, and six citizens, "two of whom shall be residents of the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State."

The following appointments and reappointments of Regents were made during the year: By appointment of the Vice-President on December 7, 1905, Senator Henry Cabot Lodge in place of Senator Orville H. Platt, deceased, and Senator A. O. Bacon to succeed Senator Francis M. Cockrell, whose term of service in the Senate had expired; by appointment of the Speaker on December 13, 1905, Representatives R. R. Hitt and Robert Adams, jr., to succeed themselves, and Representative W. M. Howard in place of the Hon. Hugh A. Dinsmore, whose term as Representative had expired. By joint resolutions of Congress approved February 23 and April 23, 1906, respectively, the Hon. Richard Olney and Dr. Andrew D. White were appointed Regents for terms of six years each.

It is with deep regret that I have to record the death of the Hon. Robert Adams, jr., on June 1, 1906. Mr. Adams was a member of the Board of Regents on the part of the House of Representatives for nearly ten years, and always displayed a deep interest in the welfare of the Institution. He was succeeded by the Hon. John Dalzell, of Pennsylvania, who was appointed by the Speaker on June 12, 1906.

The membership of the Board at the end of the fiscal year was as follows:

The Chief Justice, Mr. Melville W. Fuller, Chancellor of the Institution; the Vice-President, Mr. Charles W. Fairbanks; Senator S. M. Cullom; Senator Henry Cabot Lodge; Senator A. O. Bacon; Representative R. R. Hitt; Representative John Dalzell; Representative William M. Howard; Dr. James B. Angell, of Michigan; Dr. Andrew D. White, of New York; the Hon. John B. Henderson, of the city of Washington; Dr. A. Graham Bell, of the city of Washington; the Hon. Richard Olney, of Massachusetts, and the Hon. George Gray, of Delaware.

At a meeting of the Board of Regents held March 12, 1903, the following resolution was adopted:

Resolved, That in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

In accordance with this resolution the Board met on December 5, 1905, January 24, 1906, and March 6, 1906. A special meeting was also held on May 16, 1906. The proceedings of the Board at these meetings will be found in its annual report to Congress.

GENERAL CONSIDERATIONS.

The year just passed marked an important epoch in the life of the Smithsonian Institution, the completion of its sixth decade.

Few establishments of learning have secured so wide a recognition in so limited a time, short in comparison with the history of the older universities and societies in America and covering but a brief period in the life of the seats of learning and of the academies of the Old World. This circumstance is principally due to the fact that no institution founded in trust ever had so powerful a guardian as the Government of the United States, and to the stability of policy given to the Institution by the permanence of position guaranteed to its head. It is doubtful if any other such organization in this country can point to sixty years of existence under the direction of but three men, and probably no other has been presided over in succession by

three persons of such great distinction as were called to the responsible position of Secretary.

When James Smithson bequeathed his fortune to the United States of America to found at Washington an institution for the increase and diffusion of knowledge among men, he left the broadest direction possible for the establishment of an institution of learning. He placed no restrictions whatever upon the means or methods which the United States might use in carrying out his noble idea. It is clear, however, that he had in mind that concrete means must be employed for accomplishing the purpose of his bequest, and this was the judgment of the Members of Congress for a period of ten years, while the subject of the Smithsonian bequest was under discussion, and of all the distinguished scientific men and educators whose views were sought prior to final action by the National Legislature. So broad was the idea that it required to be interpreted and defined lest the energies exercised under the fund be scattered in many directions and prove wasteful and ineffective. As long as the two purposes were kept in mind, namely, to increase the sum total of human knowledge and to spread it abroad, the objects of the bequest were being accomplished.

Congress in the act of foundation directed that the sum of nearly a quarter of a million of dollars of interest, which had accrued since the receipt of the bequest, be appropriated for the erection of a suitable building, at once giving to the new institution a local habitation and a name, and it prescribed, moreover, to what purposes this building should be put—a museum, a chemical laboratory, a library, a gallery of art, and lecture rooms. The law at once stamped the Institution with a national character by declaring that for exhibition in this building there be delivered over to the Institution all museum objects belonging to the United States which were in the city of Washington, and made the Institution coequal with the Library of Congress in the matter of receiving copyright books, engravings, and other articles. This act, however, comprehensive as it was, required further interpretation, and in addition to the purposes so clearly set forth it was decided to offer prizes for original memoirs, to make grants for special objects of research, and to diffuse knowledge by publishing a series of reports giving an account of new discoveries in science as well as separate treatises on subjects of general interest.

In brief, the new institution was to take upon itself the functions of a great museum representing the sciences, the arts, and the industries; a gallery of art; a library; an academy stimulating research and issuing publications, and a publishing house for the popularization of knowledge, and all these upon an income of what was then

not much more than $30,000 per annum. Nevertheless all these activities were undertaken and more not named were added, and by great economy and through the then larger purchasing power of money they were carried on with credit. Moreover, in view of the absence of many national scientific institutions which have since grown up, the Smithsonian, through its Secretary, was for a long period the general adviser of the Government in scientific matters. He served on the Light-House Board; he was called upon to make experiments to improve the acoustic properties of the Capitol; in times of war he advised in ordnance matters, whilst at different periods the several secretaries took up such large questions as the study of meteorology and the making of meteorological observations all over the United States, finally resulting in the formation of the United States Weather Bureau; the artificial propagation of food fishes and the investigation of problems relating to ichthyology in their bearing upon the fisheries, resulting in the establishment of the Bureau of Fisheries; or so large a problem as the practical use for the purposes of war of the principle discovered in connection with the maintenance and flight of heavy bodies through the air.

As Congress and the people generally realized that the programme of operations was vastly larger than was commensurate with the income from the fund, they endowed this ward of the Government by annual budgets and thus made what was originally a comparatively small museum a great museum of the nation; provided for the system of exchanges of Government and scientific publications between this country and other countries; maintained ethnological and archeological work on a considerable scale; established a splendid home for the custody of living animals, at once serving for the recreation and instruction of the people and affording valuable material for students; and within the past year has assisted in a vast scheme of cooperative international bibliographical work, which had its inception in a suggestion made by the first Secretary in 1855. In this and in other ways has the Government aided in carrying out the conditions which it imposed upon the Smithson bequest, coming more and more to the help of the Institution, and making its own fund freer for that portion of its programme of work which has to do with research and publication and the general diffusion of knowledge.

By a gradual and wise development of the system of administration the four or five activities of the Institution have been put into separate groups, each with a responsible head answerable to the Secretary, which renders possible the greatest freedom of action and judgment consistent with an orderly and harmonious organization. Thus, at the end of sixty years, it may be said with truth that the

name of the Smithsonian is a household word throughout the United States, that it has been carried to every land where civilization exists, and that the benefits of this foundation, while naturally inuring most strongly to the people of the land in which the establishment was created, are yet truly extended to all men, and that the United States, through its legislative and executive branches of the Government, through the distinguished men who have served upon the Board of Regents, and the great scientific leaders and thinkers—Henry, Baird, and Langley—has rendered to the world at large a more than faithful account of its stewardship of this unique bequest.

ADMINISTRATION.

The duties of the Secretary during his absence in the summer and from the time when his final illness began, in November, 1905, were performed by Mr. Richard Rathbun, an assistant secretary of the Institution, by designation of the Chancellor under authority of the act of May 13, 1884, providing for the appointment of an acting secretary. That the work progressed so well is due to the hearty support given by the entire staff in what proved to be one of the most trying years in the history of the Institution.

Dr. Cyrus Adler entered upon the discharge of his duties as assistant secretary in charge of library and exchanges on July 1, 1905, and on the same date Mr. F. W. Hodge, who, for about four years, had served as acting curator of exchanges and assistant in charge of the Smithsonian office, resumed his duties as ethnologist in the Bureau of American Ethnology.

It is gratifying to report that the current business of the Institution was conducted in a prompt and efficient manner, and that no arrearages in the work of the Government branches under its direction had to be noted in the quarterly statements made to the President and the annual statement made to Congress in accordance with law.

As has been customary, the estimates submitted to Congress in October, 1905, were accompanied by a letter explaining concisely but as forcibly as possible the reasons for requesting the amounts named in connection with each item. In the hearings on these estimates before a subcommittee of the House Committee on Appropriations, which occupied the greater part of two days in April, 1906, the workings of the Institution and its branches were fully discussed, and it is my opinion that the importance of the activities conducted under the direction of the Board of Regents is well appreciated by the members of that subcommittee.

In accordance with an enactment of Congress, the Government branches of the Institution join with the Executive Departments in drawing up each year a list of the more important supplies required during the next twelve months. Proposals are thereupon requested and awards are made to the lowest bidders. Reduced prices are secured in this manner and the machinery of purchasing is greatly simplified. The parent Institution has been privileged to share in this arrangement, greatly to its advantage.

FINANCES.

The permanent fund of the Institution and the sources from which it was derived are as follows:

Deposited in the Treasury of the United States.

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposit from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000.00	
Accumulated interest on Hamilton fund, 1895	1,000.00	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposit from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Total amount of fund in the United States Treasury		937,000.00

Held at the Smithsonian Institution.

Registered and guaranteed bonds of the West Shore Railroad Company, part of legacy of Thomas G. Hodgkins	42,000.00
Total permanent fund	979,000.00

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act organizing the Institution and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

By the final settlement of the estate of the late Thomas G. Hodgkins during the past year the Institution received, in May, 1906, the balance of the residuary legacy left by this benefactor. It amounted to $7,850, in the form of registered bonds of the United States, now recorded in the name of the Smithsonian Institution, and held subject to the order of the Board of Regents. Interest had accumulated on these bonds to the amount of $3,225.55, which sum was paid in

cash and deposited in the United States Treasury to the credit of the current account of the Institution.

The income of the Institution during the year amounted to $67.588.08, derived as follows: From interest on the permanent fund, $57.900; from interest on the Hodgkins residuary legacy, $3,225.55; from rentals, $437.53; from miscellaneous sources, $6,025—all of which were deposited to the current-fund account in the Treasury of the United States, which, through the courtesy of the Treasurer, is now receiving and collecting miscellaneous checks for the Institution, thus making unnecessary the intermediary of a bank. With the addition of the nominal balance of $5,153.92, brought forward from the previous year, the total credits for the year reached $72,742. The disbursements, which will be given in detail in the report of the executive committee, amounted to $62,557.87, leaving a credit balance on June 30, 1906, of $10,184.13.

Mr. W. I. Adams, chief clerk of the International Exchanges, was on June 12, 1905, appointed accountant of the Smithsonian Institution and disbursing agent for the Government appropriations for the National Museum, the International Exchanges, the Bureau of American Ethnology, the Astrophysical Observatory, the National Zoological Park, and such other objects as may from time to time be placed by Congress under the direction of the Institution.

Certain additional safeguards suggested by experience were adopted early in the fiscal year for the protection of the funds of the Institution and the Government.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1906:

International Exchanges	$28,800
American Ethnology	40,000
Astrophysical Observatory	15,000
United States National Museum:	
Furniture and fixtures	22,500
Heating and lighting	18,000
Preservation of collections	180,000
Transportation of exhibits acquired at the Louisiana Purchase Exposition	6,500
Books	2,000
Postage	500
Rent of workshops	4,580
Building repairs	15,000
New building for the National Museum	1,500,000
National Zoological Park	95,000
Total	1,927,880

The estimates forwarded to Congress in behalf of the Government branches under the Institution and the appropriations based thereon

for the fiscal year ending June 30, 1907, are shown in the following table:

	Estimates.	Appropriations.
International Exchanges	$28,800.00	$28,800
American Ethnology	50,000.00	40,000
Astrophysical Observatory	15,000.00	14,000
National Museum:		
Furniture and fixtures	22,500.00	20,000
Heating and lighting	18,000.00	18,000
Preservation of collections	210,000.00	180,000
Purchase of specimens	10,000.00	....
Books	5,000.00	2,000
Building repairs	15,000.00	15,000
Rent of workshops	4,580.00	4,580
Postage	500.00	500
Sunday and night opening	11,708.80	....
New building for the National Museum	750,000.00	500,000
National Zoological Park	118,000.00	95,000
International Catalogue of Scientific Literature	5,000.00	5,000
Protection and excavation, ruin of Casa Grande, Arizona	....	3,000
Total	1,264,088.80	925,880

RESEARCHES.

The fact that at the beginning of the fiscal year there were no funds to the credit of the current income of the Institution rendered it prudent that new research work should not be entered upon until at least a slight surplus to the credit of the Institution should have been accumulated in the Treasury. Accordingly, no enterprises of this character were initiated during the year, and for the same reason publications in the Smithsonian series proper were suspended for several months. Such investigations as were in progress, however, were continued, and all obligations which had been incurred for grants or publications were met.

SMITHSONIAN GRANTS.

Prof. A. M. Reese, of Syracuse University, who had received a moderate grant from the Institution for the purpose of collecting material for an embryological study of the alligator, submitted in August, 1905, an interesting account of the results of his field work in Florida. A series of nearly 300 embryos was gathered, comprising practically all the stages of development except the very early ones, which Professor Reese proposes to obtain later. Strangely enough, very little has been made known regarding the embryology of this large reptile, once so common in our southern

waters, and the material now at command will thus furnish the means for an original biological investigation of much importance.

Dr. Edward L. Greene, who, as noted in previous reports, has in course of preparation a paper to be entitled "Landmarks of Botanical History," reports satisfactory progress. The completed manuscript is to be submitted early in 1907, and it is believed that the intimate knowledge of the history of botany possessed by Doctor Greene will render its publication of great value to students in this branch of science.

The International Fishery Congress will hold its fourth general meeting in the city of Washington during the summer of 1908, and to enhance the interest in its proceedings prizes for contributions of merit have been offered by a number of organizations and individuals. In view of the importance of the occasion the Institution has tendered an award of $200 for the best essay or treatise on "International Regulations of the Fisheries on the High Seas, their History, Objects, and Results."

HODGKINS FUND.

Several important investigations are in progress under grants from the Hodgkins fund of the Institution, the results of which have not yet been fully reported. The conclusion of others has been unexpectedly delayed, and these will properly be summarized in a later report.

In March, 1906, Dr. R. von Lendenfeld announced the conclusion of the second part of the investigations on the organs of flight carried on under his direction. It relates to the air sacs of birds, and was conducted by Mr. Bruno Müller, whose report has been submitted and approved for publication by the Institution.

Another paper, on the wings of hymenopterous insects, prepared under the same supervision by Dr. Leo Walter, has also been received.

The investigation of Prof. W. P. Bradley, of Wesleyan University, to determine the relation between the initial and the final temperature of air which in flowing through a nozzle passes from a high pressure to a lower is reported as progressing satisfactorily. Opposing theories being held as to the physical principle involved in this type of expansion, special interest is felt in these experiments, and while they are not yet sufficiently advanced for a definite conclusion to be drawn from them, the present results are such as to justify a second moderate grant for their continuance during the coming year. It may be added that this investigation is expected to form an important part of an extended inquiry into the factors which make for efficiency in an air liquefier.

Under a grant from this fund Mr. A. Lawrence Rotch, director of the Blue Hill Meteorological Observatory, was enabled to continue the ascensions of *ballons-sondes* at St. Louis during the different seasons of the year and so to ascertain the annual variation of temperature in the free air at great heights. Twelve balloons were dispatched in July, 1905, and all but two of the attached instruments were recovered. Their automatic records of barometric pressure and air temperature showed an extreme height of nearly 10 miles, with the lowest temperature of 74° F. below zero at a less altitude. The place and time of the descent indicated the average direction and speed of the air currents. All of the last 21 balloons and instruments, sent up in April and May, 1906, were returned, some of them having risen 10 miles and encountered a temperature of 85° F. below zero 8 miles above the earth. At about 7 miles a relatively warm stratum was entered, which was found to be at a higher level in the summer and autumn.

In April, 1906, a Hodgkins grant was requested by Mr. S. P. Fergusson, assistant at the Blue Hill Meteorological Observatory, for a study of the differences between the meteorological conditions on the summits of mountains and at the same height in free air. An investigation of this nature being important in its bearings on dynamic meteorology, a small grant to aid in the purchase of the necessary apparatus was approved.

The apparatus adapted and arranged by Mr. Alexander Larsen for experiments in photographing the spectrum of lightning has been materially improved during the year and the results carefully reported. Several interesting photographs have been received from Mr. Larsen, although the conditions have been generally unfavorable throughout the season for securing such, as the electrical storms, which would have furnished them, have taken place in the daytime. The research will continue to be prosecuted as occasion offers. A paper by Mr. Larsen on photographing lightning flashes by a moving camera is included in the general appendix of the Smithsonian Report for 1905.

In May, 1906, a Hodgkins grant was approved on behalf of Prof. E. L. Nichols, of Cornell University, for an investigation on the properties of matter at the temperature of liquid air. The importance to the physicist and chemist of this field of research, which greatly extends the range of temperatures throughout which investigations on the properties of matter can be conducted, is recognized, and the Institution expects that the experiments to be prosecuted under the supervision of Professor Nichols will mark a definite advance in scientific knowledge in this direction. The outline of work already submitted notes progress in several interesting researches.

Preliminary measurements testing the method employed in experiments on the heat of vaporization and specific heat at constant pressure of air, nitrogen, oxygen, and hydrogen have been successfully conducted, and plans are making to extend the investigation to other gases.

The method employed in an investigation to determine the coefficient of expansion of metals and other substances at low temperatures makes use of the interference of light, and, being of extraordinary delicacy, possesses the advantage of permitting the determination of the expansion in detail throughout the entire range of temperature, instead of giving merely the mean coefficient between fixed points of widely different temperatures. The results already obtained in the case of gold, silver, aluminum, and glass are of an interesting and unexpected character, and it is the intention to extend the experiments to other substances and temperatures. A set of measurements on the Hall effect in tellurium at the temperature of liquid air has been completed during the year, and preparations are already in progress for the study of the Hall effect and of electric properties in general of silicon, tungsten, manganese, chromium, molybdenum, and other substances which have only recently become available. An extended investigation on the effect of temperature upon the magnetic properties of certain steels is reported by Professor Nichols as in progress and promises interesting results.

NAPLES TABLE.

The applications for occupancy of the Smithsonian table at the Naples Zoological Station during the past year have been numerous, and the appointments approved for the period from July 1, 1905, to June 30, 1906, aggregated sixteen months. Such action has been made possible through the courtesy of Doctor Dohrn, the director, who has on several occasions permitted the attendance of two Smithsonian representatives at the same time. As heretofore, the reports submitted by various occupants of the Smithsonian table mention with appreciation the excellent management of the station, and the unremitting efforts of all connected with it to further the work of investigators.

Dr. Stewart Paton, formerly of the teaching staff of Johns Hopkins University, who occupied the table for six months beginning November 1, 1905, secured an extension of his time through June and July, 1906. His researches relate to problems of fundamental importance in connection with the structure, development, and function of the nerves, and their relation to the cardiac movements. It is

gratifying to state that he reports success in demonstrating the presence at an early period in the embryo of a nervous system far more complicated than was previously believed to exist. In submitting an outline of his investigation, Doctor Paton applied for reappointment for an additional period and his request has been approved for five months, from October 1, 1906, to February 28, 1907. A monograph collating the results of the entire research will be published on its completion.

Mr. W. B. Bell, fellow in zoology in the State University of Iowa, had the use of the Naples table for three months from the 1st of July, 1905. His time was largely occupied in the preparation of embryological material for later study, relative to the hermit crab, *Eupagurus prideauxii* Bell. He will report at a future time upon the results of his investigation.

Although the table was already occupied by a Smithsonian representative, Dr. Harold Heath, associate professor in Leland Stanford Junior University, was received at the station for three months from January 15, 1906, and Dr. E. L. Mellus, of Baltimore, for the months of January and February, 1906, both being appointees of the Institution. Doctor Heath proposed while at Naples to conduct researches on the development of the ctenophore hydroids and on the body cavity of certain invertebrates. Formal reports, however, have not yet been received from either of these gentlemen.

Dr. M. M. Metcalf, from 1893 to 1906, professor of biology in the Woman's College of Baltimore, and now professor elect of zoology in Oberlin College, has received the appointment to the Smithsonian table for the months of March and April, 1907. It is Doctor Metcalf's intention to study the early development of the nervous system in the asexual reproduction of *Salpa*, to make observations upon certain species of the *Amœba*, and to search for indications of conjugating flagellispores similar to those noted in a fresh-water species which he has heretofore examined.

Thanks are again due to Dr. J. S. Billings, Dr. E. B. Wilson, Dr. Theodore Gill, and Dr. C. W. Stiles, who constitute the Naples Table Advisory Committee, for continued prompt and courteous aid in passing upon the qualifications of applicants for the Smithsonian table at the station.

The National Museum and the Bureau of American Ethnology of the Institution have carried on numerous biological, geological, and ethnological researches, described elsewhere in this report. Important investigations by the Astrophysical Observatory on the absorption of the solar envelope and on solar radiation have been continued, and will be referred to later.

PUBLICATIONS.

It is mainly through its publications that that vital principle of the Institution, "the diffusion of knowledge among men," is carried out. The institution proper maintains three regular series of publications, the Smithsonian Contributions to Knowledge, the Smithsonian Miscellaneous Collections, and the Annual Reports, while under its auspices are issued the annual reports, proceedings, and bulletins of the National Museum, the reports and bulletins of the Bureau of American Ethnology, and the Annals of the Astrophysical Observatory, the whole presenting a fund of information covering a wide range of human knowledge in both a specialized and general form.

The Smithsonian Contributions to Knowledge, now in their thirty-fourth volume, are restricted to the publication of positive additions to human knowledge resting on original research, all unverified speculations being rejected. The Smithsonian Miscellaneous Collections are designed to contain reports on the present state of our knowledge in particular branches of science, instructions for collecting and digesting facts and materials for research, lists and synopses of species of the organic and inorganic world, reports of explorations, and aids to bibliographical investigations. This series is now in its forty-ninth volume, and in the Quarterly Issue provision has been made for the early publication of short papers descriptive of new discoveries or containing information of current interest in all departments of science.

These two series of publications are printed at the expense of the Institution. Owing, however, to the lack of funds heretofore mentioned, their issuance was necessarily suspended during the early part of the year, but toward the close there was a partial resumption of the work. The printing of the memoir on "Atmospheric Nucleation," by Dr. Carl Barus, in the Contributions, was completed, and several papers were published in connection with the Quarterly Issue.

The last edition of the Smithsonian Geographical Tables having been exhausted, a new one, embodying some minor corrections by the author, Prof. R. S. Woodward, now president of the Carnegie Institution, was put to press near the end of the year. A revision of the Meteorological Tables, for which there is also a great demand, is in course of preparation.

There is under consideration a request that Bowen's Vocabulary of the Yoruba languages, published by the Institution in 1858, be reprinted for the use of missionaries in the Yoruba country of West Africa, those making the proposition regarding it as the most useful and accurate book dealing with the various phases of Yoruba

life. It is interesting to note that a work of this character, issued by the Smithsonian nearly fifty years ago, should still remain a standard of authority.

In view of the increased interest and importance attaching to the subject of earthquakes on account of the disaster to San Francisco and its vicinity on April 18, 1906, it has been decided to publish a supplement to the "Catalogue of Earthquakes on the Pacific Coast from 1769 to 1897," compiled by Dr. E. S. Holden and published in the Smithsonian Miscellaneous Collections in 1898. The work will be prepared by an official of the United States Weather Bureau, and will bring the subject down to date. Through the courtesy of the Department of State and of the Hydrographic Office of the Navy Department, the Institution has also received information regarding recent earthquakes in Venezuela and other regions, which is available for publication.

The annual report of the Board of Regents to Congress, which is printed at the Government Printing Office, has been the chief medium through which the Institution has been enabled to disseminate scientific information to the world at large. Besides the official account of the operations of the Institution, this report has for over half a century included a general appendix giving a record of the progress in different branches of knowledge, compiled largely from journals in foreign languages, and the transactions of scientific and learned societies throughout the world. The considerable number of copies of this publication placed by Congress at the disposal of the Institution has rendered possible a wide distribution to important libraries and institutions of learning, but the allotment is wholly insufficient to supply more than a small fraction of the individual requests, and the popular demand for the volume has so constantly increased that the entire edition of each year's report is exhausted within a few months of its appearance.

The Proceedings of the United States National Museum, the first volume of which was issued in 1878, are intended as a medium for the publication of original papers based on the collections of the Museum, setting forth newly acquired facts in biology, anthropology, and geology, or containing descriptions of new forms and revisions of limited groups. A volume is issued annually or oftener, for distribution to libraries and scientific establishments, and in view of the importance of the more prompt dissemination of new facts, a limited edition of each paper is printed in pamphlet form in advance. The dates at which these separate papers are published are recorded in the table of contents of the volume. The Museum Bulletins, publication of which was begun in 1875, comprise a series of more elaborate papers, issued separately, and, like the Proceedings, based chiefly, if not wholly, on the collections of the Museum. A quarto

form of the bulletin, known as the "Special Bulletin," has been adopted in a few instances in which a larger size of plate was deemed indispensable. Since 1902 the volumes of the series known as "Contributions from the National Herbarium," and containing papers relating to the botanical collections of the Museum, have been published as bulletins.

The annual report of the Museum is printed as a separate volume of the report of the Board of Regents to Congress.

The publications of the Bureau of American Ethnology, consisting of annual reports and bulletins, relate to the operations of the Bureau in its various branches of exploration and research. The most important work now in course of printing is a bulletin in two volumes entitled "Handbook of the Indians," which will contain a summary of all the information collected regarding the Indian tribes of the United States, arranged in alphabetical sequence for convenience of reference.

Volume I of the Annals of the Astrophysical Observatory was published in 1900. A second volume, which has been in preparation for some time, is nearly ready for the press. It will discuss the continuation of the work of the Observatory in Washington and also the investigations on solar radiation conducted by a Smithsonian party at the solar observatory of the Carnegie Institution on Mount Wilson, California.

Two memoirs by the late Secretary Langley, entitled "Experiments in Aerodynamics" and "The Internal Work of the Wind," were printed in 1891 and 1893, respectively, as parts of Volume XXVII of the Smithsonian Contributions to Knowledge. A third paper, dealing with later experiments on the same subject, was to complete the volume. At the time of Mr. Langley's demise the manuscript was mostly prepared, but it required revision and the writing of several chapters on the engineering part of the work; and by an arrangement with Mr. Charles M. Manly, who was for a number of years Mr. Langley's chief assistant in aerodynamics, the memoir has been placed in his hands for completion.

The Annual Report of the American Historical Association for the year 1905 was transmitted to Congress on May 14, 1906, under the requirements of the act of incorporation of the association. The Smithsonian Institution is by law allowed a number of copies of the reports of this association, which are distributed in exchange for the publications of various foreign and American historical societies.

There was also forwarded to Congress the eighth report of the National Society of the Daughters of the American Revolution, in accordance with the act of incorporation of that organization.

In order that the practice of the Institution in the supervision of its publications might correspond with that of the Executive Depart-

ments as prescribed in the President's order of January 24, 1906, an advisory committee on printing and publication was appointed by the Acting Secretary on February 7, 1906, whose personnel is as follows:

Dr. Cyrus Adler, Assistant Secretary, chairman; Dr. F. W. True, of the United States National Museum; Mr. F. W. Hodge, of the Bureau of American Ethnology; Dr. Frank Baker, of the National Zoological Park; Mr. C. G. Abbot, of the Astrophysical Observatory; Mr. W. I. Adams, of the International Exchanges; and Mr. A. Howard Clark, of the Smithsonian Institution.

The committee has held twenty-six meetings and has examined and reported on fifty-four manuscripts submitted for publication, besides numerous blank forms to be printed for use in the bureaus of the Institution. It has also advised the Acting Secretary on many matters connected with the question of printing and binding.

For the guidance of the several branches of the Institution in the preparation of manuscript and the correction of proofs the following rules, recommended by the advisory committee, were issued in March, 1906:

1. Typewritten copy is preferred. Ordinary manuscript will be accepted if the handwriting is clearly legible throughout.

2. The sheets of manuscripts should be of uniform size and consecutively numbered. The writing should be on one side of the sheets only.

3. The subject-matter of manuscripts should be maturely considered and carefully revised by authors, everything unnecessary and irrelevant being excluded. Particular attention should be paid to paragraphing, punctuation, the insertion of side headings, references to illustrations, etc., as only a limited amount of correction in these particulars will be allowed in proof.

4. The whole of the manuscript must be submitted at one time, and with it all the tables and illustrations that are to be used.

5. Illustrations should be used only when necessary for the elucidation of the text; never for mere embellishment. The copy for colored or other expensive illustrations should not be prepared, nor should they be employed, without special authority.

6. A list of illustrations, giving their titles in brief and such explanations as may be necessary, should accompany the manuscript. Upon each illustration should be noted its number and a reference to the manuscript page to which it relates. The places where plate and figure references are to be inserted in the text should be indicated in the manuscript.

7. The use of tables should be avoided whenever it is practicable to present results in a summarized form, and all tables should be condensed as far as possible.

8. In order to avoid unnecessary work in the preparation of extended treatises, authors are urgently recommended to submit in advance to the head of the bureau to which such treatise pertains an outline in writing of its proposed contents, stating the probable size of the manuscript and the number of illustrations required. Extended treatises should be accompanied with a table of contents in which the relative importance of headings is indicated.

9. Galley proof, upon which reasonable corrections and indispensable additions may be made, will be sent to the authors whenever practicable. If in

correcting proof an author exceeds what seems to the editor reasonable, the latter will exercise his discretion as to the revisions to be accepted. No material changes will be permitted in page proof.

10. Editors employed under the Smithsonian Institution are required to see that manuscripts conform with the foregoing rules before they are sent to press. If this can not be accomplished by conference with the author, the matter must be referred to the head of the bureau under which the manuscript is to be published.

11. When ready for the press, the editor will send manuscripts to the head of the bureau to which they pertain, with a statement that they are in every respect ready for the printer and that the accompanying illlustrations are necessary.

12. An editor shall not depart from the form established for any series of publications without the knowledge and consent of the head of the bureau under which he is employed. When a departure from approved standards of publications seems desirable, the editor should obtain a sample page for criticism and approval before the printing proceeds.

13. It is the duty of editors to see that copy for illustrations is suitable in kind and quality for the processes of reproduction proposed to be employed, and also to see that figures (especially those in outline) are reduced to a size as small as practicable for the purpose intended. All illustrations should be marked to show the size and the process of reproduction desired.

14. Editors should see that every volume is supplied with a suitable index.

Upon the recommendation of the International Commission on Zoological Nomenclature that genera hereafter described be assigned a type species, a rule was issued on April 3, 1906, providing that "a type species shall be designated for every new genus of animal or plant proposed in the publications of the Smithsonian Institution, and it shall be the duty of the editors to see that no new genera are published without such designation."

Two important laws relating to public printing were passed by Congress at the last session and approved by the President on March 30, 1906. One of these provides that from the general appropriation for public printing and binding an allotment shall be made to each Department or independent office of the Government, and that to each shall be charged the first cost of publishing all reports emanating from such Department or office. The custom heretofore has been to charge the entire cost of all public documents, except in a few specific cases, against the general appropriation without restricting the Departments in this particular.

The other law prevents accumulations of large numbers of documents by providing that they shall be printed in several editions as the demand may require, the total number, however, not to exceed that authorized by law.

The first of these laws rendered it necessary that the allotment made annually to the Institution for printing the proceedings and bulletins of the Museum be extended to include the cost of the annual reports of the Institution and Museum, the reports of the

American Historical Association, and the reports and bulletins of the Bureau of American Ethnology, all of which had previously been printed under the general appropriation for public printing and binding. The allotment made for these objects for the year ending June 30, 1907, aggregates $70,000, itemized as follows:

For the Smithsonian Institution, for printing and binding the annual reports of the Board of Regents, with general appendixes	$10,000
Under the Smithsonian Institution, for the annual reports of the National Museum, with general appendixes, and for the annual report of the American Historical Association, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library	39,000
For the annual reports and bulletins of the Bureau of American Ethnology	21,000

THE LIBRARY.

The total accessions during the year to the Smithsonian deposit in the Library of Congress and to the libraries of the Secretary's office, the Astrophysical Observatory, the National Museum, and the National Zoological Park aggregated 33,358. There were also numerous additions to the library of the Bureau of American Ethnology, which is separately administered.

One of the most important acquisitions was a unique Tibetan manuscript entitled "Transcendental Wisdom," received as a gift from the government of India, which has been deposited in the National Museum. A notable gift to the Museum library was the work descriptive of the Heber R. Bishop collection of jades and other hard stones. This publication, which was presented by the Bishop estate, is in two volumes of extraordinary size, prepared in the highest style of the bookmaker's art, the edition being limited to 100 copies. The Gen. John Watts de Peyster library on Napoleon and other subjects was increased by 1,234 volumes.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The International Catalogue of Scientific Literature is a classified authors' and subject catalogue of all original scientific papers published throughout the world. The organization consists of bureaus, established in each of the civilized countries, whose duty it is to furnish references to the scientific publications issued within their several regions, these references being assembled, edited, and published in seventeen annual volumes by a central bureau in London.

The cost of printing and publishing is met by the subscribers to the Catalogue, and American scientific universities, libraries, and

scientific societies alone have shown their appreciation of the work by making advance subscriptions amounting to over $30,000. The cost of collecting and indexing the material for the Catalogue is in each case borne by the countries taking part in the work and is for the most part derived from direct governmental grants.

The work has been going on since 1901, the organization having published up to the present time sixty-seven volumes. In the beginning of the undertaking the Smithsonian Institution, realizing the value and importance of the work, undertook to represent the United States, and each year made a small allotment to temporarily conduct it here. As it was realized that even the small sum which the Institution was able to devote to this purpose was a serious drain on its resources, the Board of Regents on March 6, 1906, adopted the following resolution:

Resolved, That it is the sense of the Board of Regents of the Smithsonian Institution that the work of the International Catalogue of Scientific Literature be continued, and that application be made to Congress for a sufficient annual appropriation to enable this work to be carried on under the direction of the Institution.

The Acting Secretary, in carrying out the directions of the Board of Regents, submitted an estimate of $5,000 to provide for the necessary expenses, which amount was appropriated in the sundry civil bill and became available on July 1, 1906.

The magnitude of the work will be appreciated when it is said that since the beginning of the undertaking in 1901 the London Central Bureau has received for publication over 750,000 reference cards, of which 92,492 were furnished by the Smithsonian Institution, representing the original contributions of American scholars to the natural and physical sciences.

The limited funds at the disposal of the Institution have considerably delayed and embarrassed the work in this country. The system as at present organized is, however, capable of expansion at any time, either into fields not at present embraced within the scope of the work or in adding to the manner of presenting the index. Monthly or quarterly cards or pamphlets might, for instance, be published immediately after the appearance of the publications indexed, but such methods would only serve as adjuncts to the volumes, which would always be the permanent records.

Recently a plan has been adopted whereby authors of papers are in special cases communicated with, in order that through cooperation the subject-matter may be completely treated from the point of view of both the author and the bibliographer. While this method entails considerable clerical work, the results seem to justify the effort. Another plan which is being gradually worked out is to send to each author from time to time a list of his papers which have been indexed

at the Institution for the Catalogue, with the request that attention be called to any omission or errors. These two plans, were it possible to devote sufficient time to them, would render the work as exact as it is possible to make a complex index. Besides the value of these plans for the Catalogue itself, they keep the Institution in relation with the entire body of scientific workers in the United States and incidentally result in considerable accessions to the Library.

The supreme control of the Catalogue is vested in an international convention, and during the interval between two successive meetings of the convention the administration is conducted by an international council. A meeting of the International Convention was held in London in July, 1905, and was attended by Dr. Leonhard Stejneger, of the United States National Museum, as delegate of the Smithsonian Institution. In view of the success already achieved by the Catalogue, the convention determined to continue it for a further period of at least five years.

PRESERVATION OF AMERICAN ANTIQUITIES.

For several years there has been increasing necessity for legislation to prevent the wanton destruction of the interesting aboriginal ruins in the southwestern part of the United States, and a law, approved June 8, 1906, prohibits the excavation, injury, or destruction of any prehistoric ruin or monument on lands under the control of the United States without the permission of the secretary of the Department of the Government having jurisdiction. It further provides that the President may by proclamation declare such historic sites and prehistoric structures to be national monuments.

The sundry civil act approved June 30, 1906, contains an appropriation of $3,000, to be expended under the supervision of the Secretary of the Smithsonian Institution for the protection of the Casa Grande ruin in Pinal County, near Florence, Arizona, and for excavations on the reservation.

GIFTS TO THE INSTITUTION.

The Institution has from the beginning been the recipient of many gifts from individuals and establishments, but these have not been enumerated in detail in the Secretary's report. The donations of books and pamphlets are referred to in the report of the Library, and of objects and specimens in that of the Museum, while the two large collections of art acquired during the year are discussed on a subsequent page under the heading "National Gallery of Art."

Mention should be made here, however, of the fact that the heirs of Secretary Langley presented to the Institution the medals and

tokens received by him in recognition of his contributions to the advancement of knowledge, including the Rumford gold medals from the American Academy of Arts and Sciences and the Royal Society of London, the Henry Draper gold medal from the National Academy of Sciences, and the gold medal from the Academy of Sciences of the Institute of France, and also the Rumford silver medals from the American Academy of Arts and Sciences and the Royal Society of London.

CORRESPONDENCE.

One of the important duties of the Institution is the conduct of its correspondence, not alone such as relates to its administrative affairs, but likewise to the mass of inquiries received from all parts of the country and indeed from every quarter of the globe, regarding almost every conceivable subject. It is not the policy of the Institution to encourage such requests unless they pertain to matters included within its scope, in which event, however, every effort is made to improve the opportunity for increasing or diffusing knowledge in accordance with the prime purposes of its foundation. Inquiries relating to subjects within the scope of other governmental agencies are referred to the proper sources of information and the writers so informed, but the amount of correspondence along legitimate lines of inquiry is very great and entails much labor upon both the scientific and the clerical staffs.

In addition to the correspondence handled directly from the offices of the Institution proper, each of the bureaus under its direction conducts its own correspondence with large numbers of individuals and institutions desiring information upon the subjects to which their activities relate. The National Museum, for example, sends out annually thousands of letters concerning specimens transmitted for identification and a knowledge of their characteristics, while the National Zoological Park disseminates much valuable data regarding living animals. A large amount of authentic information about the American Indian, present and past, emanates annually from the Bureau of American Ethnology of this Institution. There is also a growing public interest in matters relating to astrophysics, and to the component elements in the sun and other celestial bodies, as manifested in a rapid increase in the amount of correspondence received by the Institution regarding this branch of scientific investigation.

Numerous letters are received from inventors making application for grants of money with which to develop their various devices, or asking an expression of the Institution's opinion as to the merits of their respective inventions. The Institution has no funds from which such aid can be given, and the Secretary is, moreover, obliged

to refuse all requests for an opinion in these matters, since such action is prohibited by a decision of the Board of Regents. The Institution furthermore does not endeavor to supply information of a commercial nature, such as is customarily furnished for a fee by engineers or other professional advisers.

In spite of these restrictions, however, the correspondence is, as has been stated, an important agency in the diffusion of knowledge.

EXPOSITIONS, CONGRESSES, AND CELEBRATIONS.

Expositions.—The Institution and its bureaus were represented at the Lewis and Clark Exposition, held in Portland, Oregon, from June 1 to October 15, 1905, mainly by a selection from the objects which had been exhibited at the Louisiana Purchase Exposition, as narrated, on a subsequent page, in the report of the representative Dr. Frederick W. True.

Models of the Langley aerodrome, some photographs and books, and a number of plane surfaces and other apparatus were lent for an exhibition by the Aero Club of America, held in New York from January 13 to 20, 1906. This club subsequently adopted a series of resolutions expressing its appreciation of the important achievements of Secretary Langley in investigating the laws of dynamic flight and in the construction of a series of working models which on trial had successfully demonstrated the principles of mechanical flight.

Congresses.—The Institution was invited to participate in a number of international congresses including the Congress of Anthropology and Prehistoric Archeology, held in Monaco in April, 1906, but the duties of the staff were so exacting during the year that it was found impossible to detail any of its members to be present at these important scientific gatherings.

Franklin celebration.—The two hundredth anniversary of the birth of Benjamin Franklin was celebrated at Philadelphia by the American Philosophical Society, from April 17 to 20, 1906, the Institution being represented by Senator Henry Cabot Lodge, a Regent. A formal address, suitably engrossed, was presented to the society, and the Institution received a copy of the commemorative medal struck in honor of the occasion.

Aberdeen University.—In response to an invitation to participate in the ceremonies attending the four hundredth anniversary of the founding of the University of Aberdeen, to take place in September, 1906, Prof. Frank Wigglesworth Clarke, honorary curator of the division of minerals in the National Museum, has been appointed to represent the Institution on that occasion.

MISCELLANEOUS.

National Academy of Sciences.—In accordance with the custom of many years the National Academy of Sciences was granted the use of the lecture hall in the National Museum for its annual meeting from April 16 to 18, 1906.

California Academy of Sciences.—The Institution has assisted the California Academy of Sciences in rehabilitating its library, which was entirely destroyed by the earthquake and fire at San Francisco in April, 1906, by duplicating, as far as possible, the sets of the Smithsonian publications and by soliciting and forwarding to the academy the published works of learned institutions in this country and abroad.

Fire protection of buildings.—During the fiscal year a committee was appointed to examine the buildings of the Institution and the Museum and to suggest regulations for their further safeguard against danger from fire. The report of this committee contained valuable recommendations, which have been put into effect.

International Bureau of Ethnography.—At the Congress on the Economic Expansion of the World, held at Mons, Belgium, in September, 1905, a number of recommendations were formulated, including one for the organization by the Belgian Government of an international bureau of ethnography, whose purposes were stated to be—

1. The framing of ethnographical and sociological interrogatories.
2. The transmission of these interrogatories through the proper authorities to colonial officers, explorers, etc.
3. The publication of the answers to such interrogatories.
4. The distribution of these answers, and cooperation in the investigations.

The Smithsonian Institution was invited to cooperate in the organization and promotion of the objects of this bureau, but after careful consideration it was found that most of the objects to be secured thereby were already included within the scope of the present activities of the Institution and its bureaus, particularly in the National Museum, where all collections belonging to the United States are deposited, and in the Bureau of American Ethnology, which is engaged upon investigations of the primitive peoples of this country. The National Museum is at all times prepared, so far as its collections allow, to enter into exchange relations with the museums of other countries, and this part of the proposed scheme could be carried on among the various countries that are interested without the establishment of a new bureau.

It was found, moreover, that a very considerable share of the general expense incident to the proposed international bureau would

entail upon the United States without the possibility of a commensurate return. Since it is enabled by its present system to informally obtain most of the international advantages which would be obtained through the proposed organization, the Institution, while acceding in principle to the project, nevertheless felt obliged to decline an active participation therein.

NATIONAL GALLERY OF ART.

The curatorship of the art collections of the nation was confided to the Smithsonian Institution by the Congressional act of 1846, providing for its establishment, in terms as follows:

> Whenever suitable arrangements can be made from time to time for their reception, all objects of art and of foreign and curious research, and all objects of natural history, plants, and geological and mineralogical specimens belonging to the United States * * * shall be delivered to such persons as may be authorized by the Board of Regents to receive them, and shall be so arranged and classified in the building erected for the Institution as best to facilitate the examination and study of them.

During its early years this object was promoted in various ways: Rooms for the gallery of art were especially designed in the Smithsonian building, a very valuable collection of prints and engravings assembled by the Hon. George P. Marsh was purchased, a selection of casts was secured abroad, and loan collections of paintings and sculpture were placed upon exhibition. In 1866 the prints were placed for temporary safe-keeping in the Library of Congress, and in 1874, and again in 1879, various art objects belonging to the Institution were deposited in the Corcoran Gallery of Art, which had been established a few years before. With the definite organization of the National Museum, art collections of various classes were secured, notably in the graphic arts, ceramics, metal, lacquer work, ivories, etc.

Suitable fireproof quarters for the collections belonging to the Institution were subsequently provided under a special appropriation by Congress, but their recall was deferred until 1896, when formal action in the matter was taken by the Board of Regents. Some of the prints, however, are still at the Library of Congress, and a few other works of art, notably a large painting by Healy, at the Corcoran Gallery.

While the title "Gallery of Art" may have seemed presumptuous for this small though relatively valuable collection, recent events have justified the expectation that sooner or later the nation was certain to possess such a gallery of genuine merit. Two benefactions are to be recorded in the history of the past year, both so far exceeding any previous ones as to mark a distinctively new era

in the building up of the National Gallery of Art. One of these was a gift from Mr. Charles L. Freer, of Detroit, Michigan; the other a bequest from the late Harriet Lane Johnston, of Washington.

THE ART COLLECTIONS OF CHARLES L. FREER.

Under date of January 3, 1905, Mr. Charles L. Freer, of Detroit, Michigan, transmitted to the Institution an offer to bequeath or make present conveyance of title to his valuable private art collections to the Smithsonian Institution or the Government, under certain conditions, proposing at the same time to provide for the construction, after his death, of a building of appropriate design and proportion to receive the collections, provided that the Institution or the Government would undertake its maintenance. Consideration was given to this proposal by the Board of Regents at several meetings, and on January 24, 1906, the offer was accepted on terms slightly modified by Mr. Freer, as conveyed in a letter addressed to the President of the United States, as follows:

WASHINGTON, D. C., *December 15, 1905.*

To the PRESIDENT:

Permit me to repeat my offer to bequeath my art collections to the Smithsonian Institution or to the United States Government, and also the sum of $500,000 in money for the purpose of constructing a suitable building in which to house them, upon the following terms and conditions:

First. The sum of $500,000 shall be paid by my executors to the Regents of the Smithsonian Institution or the United States Government promptly after my decease, and shall be used forthwith for the construction of a fireproof building connected with the National Museum, the construction of which has been recently authorized, or reasonably near thereto.

Second. The interior of this building shall be arranged with special regard for the convenience of students and others desirous of an opportunity for uninterrupted study. A suitable space shall be provided in which the Peacock Room should be re-erected complete. The whole interior arrangement of the building shall be agreed upon between the Regents of the Smithsonian Institution and myself within a reasonable time after the acceptance of this offer.

Third. The collections, with such additions thereto as shall be made during my lifetime, shall be delivered by my executors to the Regents immediately after the building is constructed and ready to receive them.

Fourth. The collections and the buildings shall be cared for and maintained perpetually by the Smithsonian Institution or the United States Government at its own expense.

Fifth. No addition or deduction shall be made to the collections after my death, and nothing else shall ever be exhibited with them, or in the same building, nor shall the said collections, or any part thereof, be removed at any time from the said building except when necessary for the purpose of making repairs or renovations in the building.

Sixth. No charge shall ever be made for admission to the building or for the privilege of examining or studying the collections.

Seventh. The collections and building shall always bear my name in some modest and appropriate form.

In lieu of the foregoing offer, I am willing, upon the conditions above expressed, to make a present conveyance of the title to said collections to the Institution or the Government, and a bequest of the sum of $500,000 for the building, provided:

1. The collections shall remain in my possession during my life, and in the possession of my executors after my death until the completion of the building.

2. I shall have the right to make such additions to the collections as may seem to me advisable or necessary for the improvement of the collections, or any of them.

3. On or before April next I will file with the officials of the Smithsonian Institution or the United States Government a descriptive inventory of the objects belonging to the collections.

4. Both I and my executors shall be free from any liability on account of any loss in or danger that may accrue to the collections while in my or their charge, even though such loss or injury shall occur by reason of my or their negligence, or the negligence of my or their servants, agents or employees.

The exact form of the bequest or gift, and the details for carrying it into execution, are legal questions that can be agreed upon by counsel representing the Institution or the Government and myself.

I am, with great respect, very sincerely yours,

CHARLES L. FREER.

Following is the resolution of acceptance, adopted by the Board on January 24, 1906:

The Board of Regents, recognizing the great value to the people of the United States of the art collection so generously offered by Mr. Charles L. Freer, of Detroit, Michigan;

Resolved, That the Board of Regents of the Smithsonian Institution do hereby accept the tender of Mr. Freer to make present conveyance to the Institution of the title to his art collection, and to bequeath to the Institution the sum of $500,000 for the construction of a fireproof building in which to house it, under the terms as stated in his communication to the President of the United States dated December 15, 1905.

The conveyance was finally executed on May 5, 1906, in the following terms:

Know all men by these presents that Charles L. Freer, of the city of Detroit, county of Wayne, and State of Michigan, party of the first part, for and in consideration of the sum of one dollar and of other valuable considerations to him in hand paid by the Smithsonian Institution, an establishment created by act of Congress, party of the second part, the receipt whereof is acknowledged, has bargained and sold, and by these presents does grant and convey unto the said party of the second part, and unto its successors, the art objects belonging to said party of the first part and now in his possession at No. 33 Ferry avenue east, in the city of Detroit, Michigan, particularly enumerated in the printed inventory hereto attached and made a part hereof: to have and to hold the same unto the said party of the second part, and its successors forever.

The said party of the first part for himself, his heirs, executors and administrators, does covenant and agree to and with the said party of the second part, and its successors, to warrant and defend the sale hereby made of said property, goods and chattels unto the said party of the second part, and its successors, against all and every person or persons whatsoever.

This transfer and sale is made by said party of the first part, and is accepted by said party of the second part, upon the following terms and conditions, which are hereby declared to be binding obligations upon the parties hereto:

1. Said first party shall bequeath to said party of the second part under the terms of his last will and testament the sum of five hundred thousand dollars, which shall be paid by the executors of said party of the first part to said party of the second part promptly after the death of said party of the first part. Said sum shall be used forthwith after the receipt thereof by said party of the second part exclusively in the construction and equipment of a fireproof building connected with the National Museum, or reasonably near thereto, upon a site to be furnished by said party of the second part, according to plans and specifications which shall be agreed upon as soon as may be after the date hereof between said party of the first part and the Regents of said Institution; provided that any portion of said sum that shall remain unexpended after a building planned to take said sum for its construction and equipment shall have been completed may be used by said Institution for purposes connected with said building and its collection. Said building shall be used exclusively for storing and exhibiting the objects covered by this instrument and such objects as may hereafter be transferred by said first party to said second party. In the event that plans and specifications are not agreed upon prior to the death of said first party, said building shall be constructed and equipped by said Institution with the sum so bequeathed with special regard for the convenience of students and others desirous of an opportunity for uninterrupted study of the objects embraced hereunder. A suitable space shall be provided in said building in which the Peacock Room mentioned in said inventory shall be re-erected complete.

2. Said first party may add other appropriate objects, to be selected by him, to those enumerated in said inventory, and such other objects when transferred to said second party shall be subject in all respects to the terms and conditions enumerated in this instrument.

3. The objects embraced in said inventory, with such additions thereto as shall be made by said first party during his lifetime and transferred to said second party, shall be delivered by the executors of said first party to said Institution in said building immediately after the building shall have been constructed and ready to receive them.

4. The said building, when constructed, and the objects when delivered, shall be cared for and maintained perpetually by said second party, or its successors, at its own expense.

5. After such delivery no addition shall be made to said objects, nor shall any deduction be made therefrom, and no other objects of any kind shall ever be exhibited in connection with said objects, or in the same building, nor shall the said objects, or any part thereof, be removed at any time from said building, except when necessary for the purpose of making repairs or renovations in the building.

6. No charge shall ever be made for admission to the building nor for the privilege of examining or studying the objects contained therein.

7. The collections and building shall always bear the name of said first party in some modest and appropriate form.

8. All objects covered by said inventory and by said subsequent transfers shall remain in the possession of said first party during his lifetime, and in the possession of his executors after his death until the said building is fully completed. Said first party shall have the right during his lifetime to loan any of said objects for exhibition purposes.

9. Said first party and his executors shall be free from any liability on account of any loss in or damage that may accrue to the whole or any of said objects before the delivery thereof to said second party, notwithstanding the fact that such loss or damage may accrue by reason of his or their negligence or the negligence of his or their servants, agents or employees.

It is the intention and meaning of the parties hereto that the title to the objects mentioned in the inventory hereto attached passes immediately to said second party, and that the title to all objects which may be added to those in said inventory mentioned, and which may be covered by subsequent transfers to said second party, shall pass immediately to said second party, upon the delivery to it of each instrument of subsequent transfer.

In witness whereof the said party of the first part has hereunto set his hand and seal, and said party of the second part has caused this instrument to be executed in duplicate by its Acting Secretary and its seal to be hereto affixed, this fifth day of May, 1906.

(Signed) CHARLES L. FREER, [SEAL.]
SMITHSONIAN INSTITUTION,
(Signed) By RICHARD RATHBUN,
Acting Secretary.

Signed, sealed and delivered in presence of—

(Signed) HERBERT E. BOYNTON. [SEAL.]
(Signed) FRANK W. HACKETT. [SEAL.]

The printed inventory which accompanied and was made a part of the above conveyance enumerates above 2,250 objects, which may be briefly summarized as follows:

By James McNeill Whistler, 119 paintings in oil, water color, and pastel; 100 drawings and sketches, 3 wood engravings, 600 etchings and dry points, 165 lithographs, and all the decorations of the famous Peacock room. By the American artists, Dwight W. Tryon, Thomas W. Dewing, and Abbott H. Thayer, 60 paintings in oil, water color, and pastel. Of oriental paintings, 298 kakemono and makimono, 121 screens and 53 panels, by various masters of Japanese and Chinese schools, from the tenth to the nineteenth century, including Ririomin, Sesshu, Sesson, Motonobu, Tanyu, Koyetsu, Sotatsu, Korin, Kenzan, Hoitsu, Okio, and Hokusai; besides 4 albums of Japanese art and 13 Tibetan paintings. Of oriental pottery, 953 pieces from Japan, China, Korea, Central Asia, Persia, and Arabia. There is also a small collection of ancient Chinese and Japanese bronzes and some lacquer work by Koyetsu, Korin, and Ritsuwo.

THE ART COLLECTION OF HARRIET LANE JOHNSTON.

Mrs. Harriet Lane Johnston, the niece of James Buchanan, who had accompanied him when minister abroad and who was mistress of the White House during his term as President, had assembled at her home in Washington some important works of art, including a

number of paintings by distinguished masters, and numerous articles of historical interest and value. Upon her decease on July 3, 1903, it was found that she had bequeathed this entire collection to the Corcoran Gallery of Art under certain specified conditions and subject to the provision "that in the event that the Government of the United States shall establish in the city of Washington a national art gallery that the said articles shall, upon the establishment of said national art gallery, be, by the said trustees of the Corcoran Gallery of Art and their successors, delivered to the said national art gallery, and upon such delivery shall become the absolute property of the said national art gallery established by the United States."

The conditions were of such a character as to cause the Corcoran Gallery to decline the bequest. From what has subsequently been learned Mrs. Johnston seems not to have been aware that the Smithsonian Institution had been named as the depository for the objects of art belonging to the nation, possibly from the fact that it had never been formally designated as the National Gallery of Art.

The executors of the will, although desiring to carry out its intent and render possible the maintenance of the collection in its integrity in Washington, felt themselves without authority to award it to the Smithsonian Institution under the circumstances, and the Congress then in session (1903–4) was too near its close to secure what was then deemed necessary legislation, although an appropriate resolution was introduced in the Senate.

The annual message of President Roosevelt to the Fifty-eighth Congress, third session (dated December 6, 1904), contains the following clause:

> The collections of art contemplated in section 5586 of the Revised Statutes should be designated and established as a national gallery of art, and the Smithsonian Institution should be authorized to accept any additions to said collection that may be received by gift, bequest, or devise.

No action followed in Congress, but the executors of the Johnston estate still feeling it incumbent upon them to prevent the disposal of the collection by sale, filed a suit on February 7, 1905, in the supreme court of the District of Columbia, asking a construction of certain doubtful clauses in the testament. By direction of the President, the Attorney-General, on behalf of the United States, on February 10, 1905, entered its appearance in the suit, claiming an interest in the matter.

It is understood that all the legatees under the will agreed to the contention of the Government except the Harriet Lane Home, of Baltimore, founded by Mrs. Johnston, which had an interest in the residuary estate, and which, from a sense of obligation to a public charity, deemed a judicial decision necessary, although some of the

trustees of the Home were in favor of having the objects kept together as a perpetual memorial to their deceased relative and friend. On October 23, 1905, the Government filed its full answer to the bill of the Harriet Lane Home and its further petition that the United States be declared to have established a National Art Gallery at and in connection with the Smithsonian Institution. Testimony was submitted on the part of the Institution before an examiner on June 8, 1906. The decision was favorable to the Institution, and the decree of the court is of exceptional importance, since it definitely establishes the fact that the collection of art contemplated in the fundamental act is the National Gallery of Art within the meaning and intent of the law.

The full text of the decree is as follows:

IN THE SUPREME COURT OF THE DISTRICT OF COLUMBIA.

D. K. ESTE FISHER, AND OTHERS, EXECUTORS AND Trustees under the Last Will and Testament of Harriet Lane Johnston, deceased, *v.* HARRIET LANE HOME FOR INVALID CHILDREN OF BALTIMORE City, and others.	Equity, No. 25,160. Doc.

This cause coming on for hearing in respect to the subject matters set forth in the Thirteenth Paragraph of the Bill of Complaint; the allegations of the said paragraph, the Answers thereto of the several Defendants, the provisions of the Last Will and Testament and of the several codicils thereto of the Testatrix, Harriet Lane Johnston, and the testimony taken on behalf of the United States of America in support of its answer to the allegations of the said thirteenth paragraph of the Bill of Complaint, having been by the Court, (after argument of counsel for the United States of America and for the Defendant the Harriet Lane Home for Invalid Children of Baltimore City, the residuary legatee and devisee named in the said Last Will and Testament of the said Testatrix) fully considered,

It is, therefore, on this eleventh day of July, in the year 1906, by the Supreme Court of the District of Columbia, sitting in Equity, and by the authority thereof, adjudged, ordered and decreed,

That there has been established by the United States of America in the City of Washington a National Art Gallery, within the scope and meaning of that part of the codicil bearing date April 21, 1902, made by the said Harriet Lane Johnston to her Last Will and Testament, in the proceedings in this case mentioned, wherein she gave and bequeathed the pictures, miniatures and other articles, to the Trustees of the Corcoran Gallery of Art, and in the event of the Government establishing in the City of Washington a National Art Gallery, then that the said pictures and other articles above mentioned should be delivered to the said National Art Gallery and become its property; and that the said National Art Gallery is the National Art Gallery established by the United States of America at, and in connection with, the Smithsonian Institution located in the District of Columbia and described in the Act of Congress entitled an Act to establish the "Smithsonian Institution" for the Increase and Diffusion of

Knowledge among men, approved August 10, 1846, 9 Stat. L. 103, (Title LXXIII, Section 5579 R. S. U. S.) and the subsequent Acts of Congress amendatory thereof; and it is further adjudged, ordered and decreed, that the United States of America is entitled to demand and receive from the surviving Executors of the said Harriet Lane Johnston, the Complainants named in the Bill of Complaint in this case, all of the above mentioned pictures, articles of sculpture, engravings, miniatures and other articles, the same to be and become a part of the said National Art Gallery so established by the United States of America at, and in connection with, the said Smithsonian Institution.

And whereas, the said Testatrix, Harriet Lane Johnston, in bequeathing the said pictures and other articles to the Trustees of the Corcoran Gallery of Art, in and by the codicil hereinbefore mentioned to her said Will, made it a condition of the said bequest that the said articles should be kept together in a room provided for the purpose, and to be designated as the "Harriet Lane Johnston Collection;" and whereas it is apparent that it was the design of the said Testatrix if the said pictures and other articles bequeathed in connection with the same should belong to, and become a part of the National Art Gallery established in the City of Washington by the United States of America, that the above mentioned provision for the keeping together in a room all of the said articles so bequeathed, and that the same should be designated as the "Harriet Lane Johnston Collection" (prescribed as the condition upon which the same should become the property of the Trustees of the Corcoran Gallery of Art) should be the condition upon which they should become part of the National Art Gallery established by the United States of America,

Now therefore, it is further adjudged, ordered and decreed, as a condition upon which the title of the United States of America shall be acquired in the said pictures and other articles hereinbefore mentioned, that the same shall all be kept, so as to form one distinct collection, in one hall or room in one of the buildings of the Smithsonian Institution, the several classes of the said articles being arranged and located in said hall or room according to the best judgment of the Secretary of the Smithsonian Institution; and that in an appropriate, prominent and permanent way, the said Collection shall be designated and declared to be the "Harriet Lane Johnston Collection."

And it is further adjudged, ordered and decreed, that the costs of the proceedings in this case in connection with this decree shall be paid by the complainants as Executors of Harriet Lane Johnston, deceased.

WENDELL P. STAFFORD, *Justice.*

As a result of this decree the Harriet Lane Johnston collection was delivered to the Institution on August 3, 1906. It consists of 31 pieces and comprises, besides works of art, several interesting historical objects. Among the paintings are a number by well-known masters, whose productions are now difficult if not impossible to obtain. The list is as follows: Painting, Madonna and Child, by Bernardino Luini; painting, Madonna and Child, after Correggio; portrait of Lady Essex as Juliet, by Sir Thomas Lawrence; portrait of Miss Kirkpatrick, by George Romney; portrait of Mrs. Abington, by John Hoppner; portrait of Mrs. Hammond, by Sir Joshua Reynolds; portrait of Miss Murray, by Sir William Beechey; painting, The Valley Farm, by John Constable; portrait of the Prince of

Wales (King Edward VII) at the time of his visit to the United States, by Sir John Watson Gordon; portrait of Josepha Boegart, by Francis Pourbous, the younger; portrait of Madam Tulp, by Janssens; painting, a street scene in India, by E. L. Weeks; painting, "Independence," by Meyer; a valuable small Roman mosaic; an old engraving of John Hampden; painting, President Buchanan and the Prince of Wales (King Edward VII) with his suite, the Cabinet, and others, at the tomb of Washington, Mount Vernon, by Thomas Rossiter; portrait of President Buchanan, by Eichholtz; miniature of President Buchanan, by Henry Brown; marble bust of President Buchanan, by Dexter; marble bust of Mr. Johnston, by Rhinehart; portrait of James Buchanan Johnston, by Harper Pennington; marble Cupid, the likeness of Henry E. Johnston when 2 years old, by Rhinehart; the first message sent over the Atlantic cable, from Queen Victoria to President Buchanan, and the reply by the latter; silver medal commemorative of the marriage of Victoria, Princess Royal of England, to Frederick William, Crown Prince of Germany, with a letter of transmittal from H. R. H. Albert, Prince Consort, to President Buchanan; letter to President Buchanan from the Prince of Wales (King Edward VII), transmitting his portrait; two autograph letters from Queen Victoria to President Buchanan, relating to the visit of the Prince of Wales to the United States, dated June 22 and November 19, 1860; photograph of Queen Victoria, with autograph signature and date "1898," presented by the Queen to Mrs. Johnston; gavel used at the Cincinnati convention, June, 1856, at which Buchanan was nominated for the Presidency; Bible on which Buchanan took the oath of office as President, March 4, 1857.

NATIONAL MUSEUM.

The National Museum is carrying on its operations as effectively as possible, though two obstacles have for many years stood in the way of perfecting its condition—lack of space and an insufficient staff. The first of these will soon be removed, and it is hoped that action on the other will not long be delayed.

The granite structure now being erected will be monumental in character and cover a larger area than any other Government building in the city except the Capitol. Its four stories will contain nearly 10 acres of floor space, which has been laid out to meet the several requirements of exhibition, storage, and workrooms. Two years have elapsed since the ground was broken, and in view of certain unavoidable delays another like period will probably be consumed in its completion, but this length of time can not be regarded as excessive, considering the massive character of the building and

the superior quality of the materials and workmanship which enter into its construction.

The rapid growth of the national collections is only what was to be expected in a country so extensive and of such exceeding wealth of resources in its natural products, in its aborigines, and in the activities of its civilization. The illustration of all of these fields was contemplated in the original plan of organization, and contributions relating to them all have been pouring in for more than fifty years.

The Museum has never had an adequate amount of space at any period in its history, not even when it began to occupy its present brick building, since collections of sufficient extent to fill it were already on hand. The accumulation of material has gone on still more rapidly in recent years, taxing to the utmost the energies of the small staff to insure its preservation. The public halls are consequently more utilized for storage than for exhibition, and visitors find it difficult to circulate among the cases. The laboratories offer scant space for the examination of specimens, and several rented buildings are completely filled with collections of great value.

The acquisitions of the past year have amounted to over a quarter of a million specimens, pertaining to practically all of the subjects comprised in the museum classification. They were derived from a great variety of sources and largely by transfer from the Government surveys. The number of private donations and exchanges was very large, and one of the former was of unusual extent and value. It consisted of a collection of 75,000 specimens of Lepidoptera from North and South America, including many types and rare species, assembled by Mr. William Schaus and by him generously presented to the National Museum.

In connection with the work of classifying the collections the assistants and collaborators have made many important contributions to science, and the several publications of the year in which these were printed are fully up to the standard so long maintained. From the duplicates recently separated from the reserve collections nearly 20,000 specimens, made up into about 260 sets, were distributed to schools and colleges in the interest of education.

BUREAU OF AMERICAN ETHNOLOGY.

The field investigations by the Bureau of American Ethnology related to the Indians of Oregon, Colorado, New Mexico, Indian Territory, Oklahoma, Pennsylvania, and Florida, but were not as extensive as usual because of the amount of work required to be done at the office in Washington. The preparation of manuscript and reading of proofs for the Handbook of the Indians occupied the attention of most of the members of the staff and of several experts

connected with other establishments for shorter or longer periods throughout the year. This large work, which has often been referred to in past reports, will be practically a résumé of all that is known regarding the aborigines of the United States, based upon information from every possible source, including the unpublished records of the Bureau.

The matter is arranged alphabetically for convenience of reference, and the two octavo volumes of which it will consist will be profusely illustrated. From the point of view of general interest it will be the most important publication which the Bureau has issued. The correcting of the proofs of the first volume was nearing completion at the close of the year.

Considerable progress was also made on the Handbook of Indian Languages, the main part of which will consist of sketches of sixteen American languages, and reports and bulletins relating to a number of other subjects were completed or in course of preparation.

With a view to assisting the Departments of the Government having custody of the public domain in the preservation of American antiquities, under the provisions of the act of Congress approved June 8, 1906, the Bureau has been active in compiling a card catalogue of archeological sites, especially the ruined pueblos and cliff dwellings, and has made good progress in the preparation of a series of bulletins giving information concerning these antiquities.

INTERNATIONAL EXCHANGES.

The International Exchange Service, initiated by the Smithsonian Institution in the early years of its existence, for the interchange of scientific publications between learned societies and individuals in the United States and those of foreign countries, and later designated by the United States Government as the agency for the transmission of sets of official documents to selected depositories throughout the world, has effectually discharged the commissions intrusted to it. Of the maximum limit of 100 copies of all Government publications, authorized by law to be distributed under the direction of the Library of Congress, from time to time, to important governmental libraries in European and other countries, 80 complete or partial sets have now been assigned and are being transmitted by the exchange service to their respective destinations. Additional public documents, issued from month to month, are forwarded promply to the various depositories.

The Institution has continued its endeavor, through the proper channels, to secure the fullest cooperation on the part of all civilized governments in reciprocally receiving and distributing within their

own borders transmissions from the United States and in dispatching to this country similar sendings from its own scientific and educational institutions and citizens. Some important changes in connection with the details of this service have been made during the year, which have resulted in greater dispatch and efficiency.

Steps have recently been taken through which it is hoped that the British Government may establish a bureau of its own, thus relieving the Smithsonian Institution from maintaining a special agency in London for the receipt and distribution of exchanges with Great Britain.

It is gratifying to state that through the efforts of the Hon. W. W. Rockhill, American minister at Peking, the long-pending exchange negotiations with China have been brought to a successful conclusion, the Shanghai bureau of foreign affairs having been designated as the representative of the Chinese Government in this matter. Efforts are being made to resume exchange relations with Korea, the transmissions to that country having been carried on heretofore through the courtesy of the Russian commission of international exchanges at St. Petersburg,

Through the offices of the Department of State and of the American minister at Rome, the exchange service between Italy and the United States has been placed upon a more efficient basis. The government of Lourenço Marquez has been added to the countries to receive full sets of official documents, in exchange for which the authorities of Portuguese East Africa are to send to the United States not only the publications of Lourenço Marquez, but also those of the province of Mozambique and of different chartered companies.

The total weight of packages handled by the International Exchanges for the year was 471,559 pounds, and the number of correspondents throughout the world has reached 56,414, an increase of 4,434 over the preceding year.

I record with regret the death on June 23, 1906, of Dr. Joseph von Körösy, who had served as exchange agent of the Institution at Budapest, Hungary, since 1897. He was the first agent of the Institution for that country, and had taken special interest in the work, materially increasing the number of packages received from correspondents in Hungary. Mr. Julius Pikler was appointed, temporarily, to succeed him.

Owing to the death of Dr. Paul Leverkühn, director of the scientific institutions and library of His Royal Highness the Prince of Bulgaria, the transmission of exchanges to that country has been temporarily suspended, but it is expected that it will soon be resumed.

NATIONAL ZOOLOGICAL PARK.

In administering the affairs of the National Zoological Park, the purposes defined by Congress in the act of organization, namely, the advancement of science and the instruction and recreation of the people, have been kept constantly in view, though on account of insufficient funds it has been impossible to promote these aims to the extent desired. It is hoped that this condition will be rectified in the near future, but that the park is already an assured success and that its objects are well appreciated is evidenced by the large number of visitors, which, during the past year, exceeded half a million.

Extreme care has been taken to preserve its very picturesque natural features, and forming, as it does, an essential part of the extensive parking system of the Rock Creek Valley, the maintenance of its driveways and paths has been the subject of constant attention.

The inadequacy of the appropriations for the proper equipment of the park has made it necessary to exercise an unwise economy in the construction of its buildings and other shelters, the majority of which are of a cheap and temporary character, and sooner or later must be replaced. The large building lately planned on a substantial and permanent basis has now been in course of erection during three years, since only small annual allotments could be assigned to the purpose, and its completion must await the appropriation for 1907.

Among the pressing needs is a small building, with outlying yards, which can be used as a hospital and quarantine for sick animals and also serve as a pathological and anatomical laboratory, in partial furtherance of the primary object of the park—the advancement of science. It is hoped that funds can be spared to begin upon this structure, the importance of which is very great, during the ensuing year.

The economy of establishing a central heating plant has long been recognized, but this feature has also been delayed for the reasons already stated. A beginning was made, however, during the past year, the boilers being placed in an extension of the temporary workshop and connections made with the three nearest buildings.

Congress has recently authorized the construction of streets at short distances from the western and southeastern boundaries of the park, and it seems especially desirable that the intervening strips of land be purchased for addition to the park. On one side the projected street is close to the edge of a steep slope within the park,

while on the other the back yards of houses would extend to the park fence. The streets in question would form more appropriate boundaries than now exist in those directions, and the acquirement of the land would help to preserve the natural beauties of the park.

The number of animals in the park at the close of the year was 1,272, of which 509 were mammals, 643 birds, and 130 reptiles.

It is gratifying to record the continued cooperation of the Department of State, through its representatives abroad, in the acquisition by gift or exchange of a number of rare animals from various parts of the world.

ASTROPHYSICAL OBSERVATORY.

This Observatory was established at the instance of the late Secretary Langley, who acted as its Director, and was intended to render possible the continuation of the epoch-making researches which he initiated at Allegheny while in charge of the observatory there. Mr. C. G. Abbot, his principal assistant for a number of years, has been designated temporarily as acting director.

The buildings of the Observatory, though of a temporary character, have been kept in good repair, and the inclosure surrounding them has been enlarged to meet additional requirements of space. As a measure of protection, a small fireproof shelter has been erected in the northeast corner of the inclosure to contain the storage batteries and an alternating current generator and to serve as a distributing center for the electrical currents used in the Observatory. Continued attention has been given to the improvement of the apparatus, with the object of adapting it more effectually to the researches which are prosecuted and of increasing its delicacy and precision.

The investigations of the Observatory have been conducted along lines of definite research, and much important information relating to solar radiation and to the transparency of the earth's atmosphere and the sun's envelope has been collected. During the past year, as for some time previously, the work has been steadily directed with the aim of securing data in regard to the suspected variability of the sun. As explained in the last report, arrangements were made in the spring of 1905 to secure series of observations at a high altitude under superior atmospheric conditions, the work being also continued at Washington during the same period. This was rendered possible through the courtesy of the Carnegie Institution and the invitation of Prof. George E. Hale, director of its newly established observatory for solar research on Mount Wilson, in southern California.

The Smithsonian party, in charge of Mr. C. G. Abbot, and equipped with the necessary apparatus, reached Mount Wilson in May and remained there until the latter part of October, 1905. The weather conditions remained excellent throughout most of the season, permitting the work to go on uninterruptedly. Again, in May, 1906, Mr. Abbot returned to Mount Wilson, where his observations are expected to continue over a somewhat longer period.

Sufficient material has been assembled since the publication of the first volume of the Annals of the Astrophysical Observatory to warrant the issuing of a second volume, the preparation of which is now in progress.

Respectfully submitted.

RICHARD RATHBUN,
Acting Secretary of the Smithsonian Institution.

APPENDIX TO ACTING SECRETARY'S REPORT.

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

The subject of greatest interest continues to be the construction of the new Museum building, for which the ground was broken in June, 1904. The failure of certain of the quarries to supply granite as rapidly as was expected has caused delay in the erection of the outer walls, but otherwise good progress has been made, and at the close of the year the basement walls, as well as the heavy steel framework and brick arches for the main floor, were approaching completion.

Until the new building is ready for occupancy the national collections must continue to become more crowded each year, but the interval is now too short to occasion much concern regarding their safety. The staff could, however, be increased to some extent with great advantage at this time, especially in view of the many preparations essential to the transfer of collections, and the importance of placing the salaries of employees on the same basis as in the Executive Departments can not be too strongly emphasized.

The roofs on the present Museum building remain in as serious a condition as ever, notwithstanding the extensive repairs made and the constant oversight to which they have been subjected. Every expedient thus far applied has failed to accomplish its purpose, and in all heavy rains the leaks still prevail to an alarming degree. Driven thus to drastic measures plans were drawn up and partial contracts entered upon before the close of the year, whereby all the present main roofs will be removed and replaced by metal roofs of the best quality, without the necessity of greatly disturbing the contents of the exhibition halls below. Under the current rate of appropriation for building repairs the work will have to be extended over two or three years, but in the end the covering of the building will be in even better condition than when it was first put on.

While the building is constructed entirely of fireproof materials, yet its contents, now much crowded, are to a large extent combustible. The dividing walls between the different halls, courts, and ranges are, moreover, pierced with large openings reaching nearly to the roof, which makes of the building practically one large room over 2 acres in extent. Although every known precaution for the detection and extinguishing of a fire has been introduced, still it has been deemed prudent to isolate the several halls by filling in the openings with fireproof material, and some progress in this direction had been made before the end of the year.

With such exceptions as have been mentioned the Museum was never in so good a condition as it is to-day. Improvements are to be noted in the exhibition halls, in the reserve storage, and in the laboratories and offices. It is the overcrowding and the necessity of trusting to outside storage for the keeping of valuable collections which now gives the most concern.

ACCESSIONS.

The number of specimens added to the collections was over a quarter of a million, divided among subjects under the three departments of the Museum about as follows: Anthropology, 8,000; biology, 227,000; geology, 21,000.

The most valuable single contribution, and one of the largest ever received by the Department of Biology, was the gift from Mr. William Schaus of his collection of North and South American lepidoptera, containing 73,000 specimens and a very large number of types and rare species. Dr. W. L. Abbott, who is still continuing his systematic investigations in the Malaysian region, presented, as usual, the entire results of his year's field work, comprising a very large amount of important material chiefly from Engano and Nias islands, West Borneo, and western Sumatra. The subjects mainly represented are ethnology, physical anthropology, mammals, and other vertebrate animals. From little-known localities in the southwestern part of the United States, especially the Territories of Arizona and New Mexico, colections in ethnology and archeology to the extent of several thousand specimens were obtained through explorations by Dr. Walter Hough, of the Museum staff, in conjunction with Mr. P. G. Gates, of Pasadena, California, and by members of the Bureau of American Ethnology. Many additions were made to the Philippine collection of ethnology secured at the Louisiana Purchase Exposition, and important specimens in archeology were received from Japan, France, Algeria, South America, and Mexico.

The Museum has been for some time assembling a comprehensive collection of small arms, with the aid and cooperation of the Departments of War and of the Navy. Appreciating the interest taken here in this subject, the United States Cartridge Company, of Lowell, Massachusetts, has most generously deposited its splendid series of 569 pieces, the finest and most complete collection of its kind in the United States. Beginning with the common bow and crossbow, all typical features in the mechanical development of devices for throwing projectiles are represented, down to the most perfect gun and pistol of modern times. The display cases in which these implements are shown, 38 in number, were supplied by the company, and are excellently well adapted for the purpose. To the collection of aeroplanes have been added originals of the Lilienthal and Hargrave flying machines, and several models used by Mr. Octave Chanute in his experiments on this subject.

The collection of glassware has been greatly enriched by a gift from the Libby Glass Company of many pieces and tools illustrating the entire process of making cut glass, from the raw material to the finished article, the latter comprising exquisite examples of their workmanship. In pottery, also, many fine pieces of domestic manufacture and decoration were obtained through the members of the American Potters' Association.

An especially notable addition to the division of historic religions is a Tibetan manuscript, presented by the British Indian government. It is a treatise on Tibetan Buddhistic theology or metaphysics, written in gold characters on the black ground of 366 cardboards between covers of lacquered wood. The acquisitions in history have been numerous and important, and some of great intrinsic value. They illustrate many interesting subjects both of warfare and of domestic life.

A finely executed bust of the late Walter Reed, major and surgeon, United States Army, and chief of the Government commission which determined the relations of the mosquito to the transmission of yellow fever, has been deposited by the Walter Reed Memorial Association, and given a conspicuous place in the main Museum hall.

An exceptionally large quantity of fishes and marine invertebrates, chiefly representing explorations at the Hawaiian Islands, the Philippine Islands, and Japan, and on the northwest coast of America, were received from the United States Bureau of Fisheries. Much of the material was still unstudied, but among the fishes were the types of 143 recently described species. Mr. Robert Ridgway, who spent part of the year in Costa Rica, returned with over 1,800 specimens of interesting birds, of which more than one-third was donated by the National Museum of that country. Specimens of the same group from the Philippines and Guam were presented by Dr. E. A. Mearns.

Important collections of reptiles and batrachians were received from Japan and the Philippines; of fishes from Mexico, through the Field Museum of Natural History; of marine invertebrates from Hawaii, Japan, Burma, South Africa, and South America, and of insects from Texas, Central America, Guatemala, the West Indies, and Japan, chiefly through the Department of Agriculture. Dr. J. N. Rose brought back from his explorations in Mexico a large collection of plants, especially rich in cacti, and many specimens from different parts of the United States were transmitted by the Department of Agriculture.

The Department of Geology was chiefly enriched through transfers from the United States Geological Survey, of specimens of rocks, minerals, and fossils. The rocks illustrated detailed surveys in several regions. The fossils included many described species and figured specimens from the Miocene, Upper Cretaceous, Ordovician, Devonian, and Silurian. Especially noteworthy were several thousand Mesozoic plants, which had been worked up and described by Ward, Fontaine, Bibben, and Wieland. Two thousand Russian Ordovician bryoza were received as a gift from Dr. A. von Mickwitz, of St. Petersburg, and several hundred examples of fossil woods and plants from the Permo-Carboniferous of São Paulo and Santa Catharina, Brazil, were presented by Mr. I. C. White.

EXPLORATIONS.

The Museum depends chiefly for its scientific collections upon the explorations of the various Government bureaus and of private individuals, having scant means to expend in this direction. The principal field work by members of the Museum staff was conducted by Doctor Hough in Arizona and New Mexico, Doctor Hrdlička in Florida, Mr. Ridgway in Costa Rica, Doctor True in Maryland, Doctor Rose in Mexico, and Doctor Bassler in the southern Appalachians, Virginia, and the Mississippi Valley.

CARE AND CLASSIFICATION OF THE COLLECTIONS.

The first duty devolving upon the Museum staff is the care and preservation of the collections, all of which has been conscientiously performed and with as satisfactory results as is possible in the present crowded condition of the rooms. In fact, much improvement is to be noted for the year in the closer segregation of some parts of the reserve series, but with the effect of changing the Museum halls more and more into the condition of storerooms.

Notable progress has been made in the classification of collections, their labeling, cataloguing, and scientific arrangement, resulting in many important contributions to knowledge. The preparation by members of the Museum staff of articles for the Handbook of the Indians, soon to be issued by the Bureau of American Ethnology, necessitated extensive investigations based upon the collections in anthropology, and much was accomplished toward working up the rich ethnological material recently acquired from Malaysia, Arizona, and New Mexico.

In zoology the mammals sent from Malaysia by Doctor Abbott were the subject of much attention, the manuscript for the fourth volume of Ridgway's Birds of North and Middle America was brought nearly to completion, and a large work on the herpetology of Japan was finished. Extensive studies were made on the large collections of fishes from Japan, the Philippine Islands, the Amazon River, and the deeper waters of the Pacific Ocean. Contributions were prepared on several families and faunal collections of mollusks, on the higher crustacea from Hawaii, the fresh-water crabs from different parts of the world, the isopod crustaceans of the North American coasts, and the corals from several localities. The soundings made by the U. S. S. *Nero* in the course of its cable surveys in the Pacific Ocean were the subject of a careful study and an instructive report. The researches completed in the division of insects are represented by 33 separate papers.

The investigations in geology have related mainly to the description of meteorites and of their structure and composition. Several important contributions in paleontology on both vertebrates and invertebrates were submitted.

EXHIBITION COLLECTIONS.

The entire renovation and rearrangement of the collections of prehistoric archeology, with some additions, have made it possible to reopen the large upper hall in the Smithsonian building long devoted to this subject. The transfer to storage of some of the older collections in the Museum building has afforded the opportunity of presenting to the public some of the more recent and interesting acquisitions in ethnology. Otherwise but few changes were made in the exhibition collections beyond providing for the larger and more important exhibits returned from the Louisiana Purchase and the Lewis and Clark expositions.

MISCELLANEOUS.

Of duplicate specimens recently separated from the reserve collections, over 19,000 were distributed in 261 sets to educational establishments, and 17,500 were used in exchanges, from which valuable returns have been received. The number of specimens sent to specialists for study, to be returned again to the Museum, was nearly 20,000.

The publications issued during the year comprised the annual report of the Museum for 1904; volumes 28, 29, and 30 of the Proceedings, the first mentioned having been nearly completed the previous year; bulletins numbered 54 and 55, the former on the isopod crustaceans of North America, the latter on the oceanography of the Pacific Ocean; and part 1 of Volume X of the Contributions from the National Herbarium. The number of publications distributed, including full volumes and separate papers, was approximately 103,000.

The library of the Museum received 3,556 books and 5,432 pamphlets and periodicals, increasing the total contents of the library to 27,726 volumes and 44,075 unbound papers.

At the Lewis and Clark Exposition, in which the Institution and its several bureaus participated, the Museum collection consisted almost entirely of objects selected from the exhibits at the Louisiana Purchase Exposition, only a few additions being made thereto.

RICHARD RATHBUN,
Assistant Secretary in charge of National Museum.

APPENDIX II.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

Sir: I have the honor to submit the following report on the operations of the Bureau of American Ethnology for the fiscal year ending June 30, 1906:

Researches among the Indian tribes were conducted in accordance with the plan of operations approved by the Secretary June 5, 1905; these include investigations among the aborigines of Oregon, Colorado, New Mexico, Indian Territory, Oklahoma, Pennsylvania, and Florida, and, more especially, researches in the office of the Bureau and in various museums and libraries throughout the country. The scientific staff remains the same as during the previous year with the single exception that Mr. F. W. Hodge was transferred from the Secretary's office of the Smithsonian Institution to the Bureau, with the title of ethnologist—a step which permits him to devote his entire time to the completion of the Handbook of the Indians.

Aside from his administrative duties, the chief was occupied with the completion and revision of material for the Handbook of the Indians and in the preparation of a monographic work on the technology and art of the tribes. He also continued his duties as honorary curator of the division of prehistoric archeology in the National Museum.

Mrs. M. C. Stevenson was engaged during the early months of the fiscal year in reading the final proofs of her monograph on the Zuñi Indians, which issued from the press in December. In January she again entered the field, having selected the pueblo of Taos, New Mexico, as a suitable place for the continuation of her researches. In initiating her work in this pueblo Mrs. Stevenson encountered many difficulties and her progress was at first slow; but later, owing largely to the very courteous cooperation of the Commissioner of Indian Affairs, her study of the history, language, and customs of the tribe was facilitated, and was progressing favorably at the close of the year.

During the early part of the year Mr. James Mooney was chiefly occupied, in collaboration with other members of the Bureau, with the Handbook of the Indians, which work was continued at intervals after he took the field. On September 19, 1905, he left Washington for western Oklahoma to continue researches among the Kiowa, Southern Cheyenne, and allied tribes, partly in fulfillment of the joint arrangement between the Bureau and the Field Museum of Natural History. His stay while with the Kiowa was chiefly at the agency at Anadarko, Oklahoma. Among the Cheyenne he made headquarters at Cantonment, Oklahoma, the central settlement of the most conservative element of the tribe. Mr. Mooney returned to Washington about the end of April, and resumed work on his report, giving much attention also to the Handbook of the Indians.

Dr. J. Walter Fewkes completed during the year his report on the aborigines of Porto Rico and neighboring islands. He also prepared an account of his researches in eastern Mexico during the winter of 1905–6, conducted under a grant from the funds of the Smithsonian Institution and an allotment from

the Bureau appropriation. These papers were assigned to the Twenty-fifth Annual Report and were in type at the close of the year. Doctor Fewkes likewise made considerable progress in the preparation of a bulletin on the antiquities of the Little Colorado Valley, Arizona.

During the year Dr. John R. Swanton completed and prepared for the press all of the Tlingit material, ethnological and mythological, collected by him during previous years; and all of the ethnological, as well as a portion of the mythological material, has been accepted for introduction into the Twenty-sixth Annual Report. Doctor Swanton also interested himself particularly in the study of the linguistic stocks of Louisiana and southern Texas, many of these languages being either on the verge of extinction or already extinct; he also has in course of preparation a grammer and dictionary and an ethnological sketch of the Natchez Indians, and has made the important discovery that this people did not form a distinct linguistic stock, as has been supposed, but formed a part of the great Muskhogean family.

Mr. J. N. B. Hewitt was engaged almost entirely in investigating and reporting on etymologies of terms and names, and in elaborating and preparing important articles for the Handbook of the Indians, and also in reading proof of that important work conjointly with the other collaborators.

During the year Dr. Cyrus Thomas was engaged almost continuously on the Handbook of the Indians, assisting in final revision of the manuscript and in reading proof. During the first two or three months he assisted also in reading and correcting proofs of Bulletin 28, which treats of Mexican antiqulties—a work for which his extensive researches regarding the glyphics of middle America especially fitted him.

The manuscript of the body of the Handbook of the Indians was transmitted to the Public Printer early in July. In view of the fact that numerous tribal and general articles were prepared by specialists not connected directly with the Bureau, it was deemed advisable to submit complete galley proofs of the Handbook to each as received. While this involved considerable delay in the proof reading, the corrections and suggestions received showed the wisdom of the plan. By the close of the year all the material was in type through the letter N, and 544 pages of this, to the article "Heraldry," had been finally printed.

The work on the Handbook of Languages, in charge of Dr. Franz Boas, honorary philologist of the Bureau, has been continued. The several sketches of American languages—sixteen in number—which are to form the body of this work are now practically complete with the exception of those on the Eskimo and the Iroquois. Field work was conduted by Mr. Edward Sapir among the Yakima of Oregon and by Mr. Frank J. Speck among the Yuchi in Indian Territory.

Mr. Stewart Culin, curator of ethnology in the Brooklyn Institute Museum, whose monograph on Indian Games forms the bulk of the Twenty-fourth Annual Report, was engaged during the year in reading the proofs of that volume; but his absence in the field for a protracted period prevented its completion.

The movement for the enactment by Congress of a law for the preservation of American antiquities, which was inaugurated during previous years, was continued by various individuals and institutions, and the perfected measure became a law in June. With the view of assisting the departments of the Government having charge of the public domain in the initiation of practical measures for the preservation of the antiquities of the Southwest, the Bureau has actively continued the compilation of a card catalogue of the archaeological sites, especially the ruined pueblos and cliff dwellings, and during the year has

made much progress in the preparation of a series of bulletins to be devoted to the fuller presentation of all that is known regarding these antiquities.

In promoting this work Mr. E. L. Hewett was commissioned to proceed to New Mexico for the purpose of making a survey of the ancient remains of the Jemez plateau region, a large part of which is now included in the Jemez Forest Reserve. A preliminary report on this work was submitted immediately on Mr. Hewett's return to Washington, and later a paper was prepared in the form of an illustrated descriptive catalogue of the antiquities, to be published as Bulletin 32. In March Mr. Hewett was called on to represent the Bureau as a member of the Interior Department survey of certain boundary lines in southern Colorado, the principal object being to determine the relation of the more important ruins of the Mesa Verde region to the boundaries of the proposed Mesa Verde park, a measure for the establishment of which was pending in Congress. Shortly after the receipt of Mr. Hewett's report this measure became a law. A leading object kept in view by Mr. Hewett on this expedition was the collection of data for the compilation of a bulletin on the antiquities of the Mesa Verde region for the Bureau's bulletin series.

In February Dr. Ales Hrdlička, of the National Museum, was commissioned to proceed to Osprey, on Sarasota Bay, Florida, for the purpose of examining several localities where fossil human bones, apparently indicating great age, have been discovered. The evidence obtained appears adverse to the theory of the great antiquity of the remains, but the observations made by Doctor Hrdlička and Dr. T. Wayland Vaughan, who accompanied him as a representative of the Geological Survey, on the unusual activity of fossilizing agencies in the locality are of extreme interest.

Dr. Walter Hough, of the National Museum, who has taken a prominent part in the investigation of the antiquities of the Southwest, has in preparation for the Bureau series a bulletin on the antiquities of the upper Gila Valley.

During the year the following permits to conduct explorations on the public lands and reservations of the Southwest were granted by the departments on recommendation of the Bureau, transmitted through the Secretary of the Smithsonian Institution:

(1) In September, 1905, the Southwest Society of the Archæological Institute of America applied for permission to conduct archeological explorations on Indian reservations and forest reserves in the Southwest, the work to begin in the spring of 1906. Later, permission to make a preliminary reconnoissance during the latter part of 1905 was asked. Recommended by the Bureau; granted by the Office of Indian Affairs and the Forest Service.

(2) In January, 1906, the request of the Bureau of American Ethnology for authority to prosecute ethnological researches in New Mexico, particularly at Taos, was favorably acted upon by the Office of Indian Affairs.

(3) In April, 1906, the American Museum of Natural History, through Dr. Clark Wissler, curator of anthropology in that institution, requested permission to conduct explorations on Indian reservations in southern California. Recommended by the Bureau; granted by the Indian Office.

One application for a permit was denied, one was withdrawn, and one was pending at the close of the year.

The collections of archeological and ethnological specimens made during the year are more limited than heretofore, owing to the reduced amount of field work undertaken. The most important accession is the product of Mr. E. L. Hewett's explorations among the ancient ruins of the Jemez plateau. Other collections worthy of note are those made by Mr. Mooney in Oklahoma and by Doctor Hrdlička in Florida. All collections were transferred to the National Museum in accordance with law.

The study of the Indian delegations visiting Washington during the year was continued as heretofore. One hundred and forty-two portrait negatives were made and measurements and casts were obtained in a number of cases.

Mr. John P. Sanborn, jr., who was probationally appointed on April 6, 1905, as editor and compiler, was permanently appointed October 6, but on October 19 he was, at his own request, indefinitely furloughed. On February 16, 1906, Mr. Joseph G. Gurley was probationally appointed as editor through certification by the Civil Service Commission. The Twenty-fifth and Twenty-sixth Annual Reports and Bulletins 31 and 32 were read and prepared for the press, and proof reading of the Twenty-third and Twenty-fourth reports, and of Bulletins 30, 31, and 32 further occupied the attention of the editor, although Mr. Hodge and the various collaborators on Bulletin 30 (the Handbook of the Indians) assumed the main burden of the reading of that work.

The illustrations work, including photography, continued in charge of Mr. Delancey Gill, who was assisted, as heretofore, by Mr. H. Walther. The number of illustrations prepared for the reports was 852, and the whole number transmitted to the printer was 1,023.

During the year the Twenty-fifth and Twenty-sixth Annual Reports were submitted to the Secretary and the Twenty-fifth was transmitted to the Public Printer, the Twenty-sixth being retained in the Bureau pending the completion of the two next preceding volumes. Bulletin 30, submitted at the beginning of the year, is in press, and Bulletin 32 is in the bindery, while Bulletin 31 was transmitted to the printer toward the close of the year. The distribution of publications was continued as in former years. Bulletin 28 was published in October, and Bulletin 29 and the Twenty-third Annual Report in December.

The library remained in charge of Miss Ella Leary, who completed the work of accessioning and cataloguing the books, pamphlets, and periodicals up to date. Owing to the crowded condition of the library, about 600 publications, chiefly periodicals, received by gift or through exchange, but not pertaining to the work of the Bureau, were transferred to the library of the National Museum. During the year there were received and recorded 306 volumes, 900 pamphlets, and the current issues of upward of 500 periodicals. One hundred and fifty volumes were bound at the Government Printing Office. The library now contains 12,858 bound volumes, 9,000 pamphlets, and a large number of periodicals which relate to anthropology and kindred topics.

The clerical force of the Bureau consists of five regular employees: Mr. J. B. Clayton, head clerk; Miss Emilie R. Smedes and Miss May S. Clark, stenographers; Miss Ella Leary, clerk and acting librarian, and Mrs. Frances S. Nichols, typewriter. During the year Mr. William P. Bartel, messenger, was promoted to a clerkship and subsequently transferred to the Interstate Commerce Commission.

The property of the Bureau is comprised in seven classes: Office furniture and appliances; field outfits; linguistic and ethnological manuscripts and other documents; photographs, drawings, paintings, and engravings; a working library; collections held temporarily by collaborators for use in research, and the undistributed residue of the editions of Bureau publications.

Respectfully submitted.

W. H. HOLMES, *Chief.*

Mr. RICHARD RATHBUN,

Acting Secretary of the Smithsonian Institution.

Appendix III.

REPORT ON THE INTERNATIONAL EXCHANGES.

Sir: I have the honor to present herewith a report on the operations of the International Exchanges during the fiscal year ending June 30, 1906.

In common with the parent Institution and all of its branches the International Exchanges has suffered a great loss in the death of the Secretary, Mr. S. P. Langley. In some other place, no doubt, a fitting tribute will be paid to his memory, and his services to the Institution and to science will be adequately depicted, but I can not refrain from recalling the fact here that Mr. Langley's connection with the Institution began in 1887 in the capacity of assistant secretary in charge of exchanges, publications, and library.

During this period the operations of the exchanges have nearly trebled in the quantity and in the breadth of distribution. Throughout his term of office as Secretary Mr. Langley continued an active interest not only in the general operations of the exchanges, but even in its details, and in his annual trips abroad, made at his own expense, he invariably visited the agencies in the countries to which he went, and in other ways promoted the interests of the service. I have little hesitation in saying that Mr. Langley made the exchanges one of the principal agencies for increasing the usefulness of the Institution in foreign countries and for carrying out the intention of the founder in the "diffusion of knowledge."

The work required of this branch of the Smithsonian Institution is essentially of a business nature, though it should be added that through its operations one of the general purposes of the Institution in the diffusion of knowledge is greatly furthered. The duties of the Exchanges consist chiefly in transporting packages of books from Washington to all foreign lands, however remote, and in receiving publications from other countries for distribution throughout the United States and territory subject to its jurisdiction.

The requirements of the service necessitate the handling of many packages and a number of heavy boxes. As work of this nature could be conducted with greater facility on the ground floor, five rooms in the southeast basement of the Smithsonian building were remodeled in 1893 for the express use of the International Exchanges. These rooms have been furnished with assorting tables, bins, filing cases, and such other office appliances and supplies as are necessary for the use of clerks and other assistants. The approximate value of this property is about $2,300.

The property acquired during the year consisted principally of boxes, packing materials, stationery, and other necessary supplies, the cost of which amounted to $3,054.84.

While it has been the practice to take an account of stock on hand at the end of each fiscal year, no detailed statement of the disposition of supplies has been kept in the Exchange Office, such supplies being given out as needed by one of the clerks. There has recently been inaugurated a complete debit and credit card system for keeping the property record, which will go into effect at the beginning of the coming fiscal year. It will then be necessary

for employees in the Exchanges to present to the clerk in charge of property approved requisitions for such stationery and supplies as they may require in the discharge of their duties. A room has been specially fitted up with shelves and bins for keeping the stock on hand.

On account of the possible danger from fire, extensive changes and improvements are now being made in the electric wires which furnish light for the exchange rooms, in accordance with the recommendations of a committee appointed by yourself. This work was only begun in the latter part of June, and is not yet finished.

It may be added here that, as a further precaution, all exchange packing boxes have been removed from the halls of the Smithsonian building to a warehouse outside of the Institution. There are, therefore, now kept on hand here only a sufficient number of boxes for the immediate needs of the service. Other precautions have been taken, such as the purchasing of new hose and metallic receptacles for paper and other waste material.

So far as reported to the Institution, in only one instance during the past year has a case of exchanges gone astray. This case was addressed to the La Plata Museum, and was shipped from New York in due course, but upon arrival of the steamer at the port of Buenos Ayres it was missing from the ship's cargo. The forwarding agents in New York are now endeavoring to trace this consignment.

While two shipments of international exchanges were subject to general average charges, one consigned to Sweden and the other to South Australia, the damage to the cargoes of the vessels did not extend to the exchange cases, and they were forwarded without much delay to their destinations. The general average amounts involved were small and the distributing agencies were good enough to meet them.

During the past year a number of unclaimed packages of books from abroad, addressed to certain Government offices and individuals in this country, were sold at public auction at several of the United States custom-houses, more especially at the port of entry at Georgetown. These packages were not addressed to the Smithsonian Institution proper, but as some of them were sent to the United States Government as exchanges, this Institution, so far as possible, recovered the packages and forwarded them to their intended recipients. In each instance the sender was fully written regarding the proper manner of transmitting exchanges to this country. Had these consignments, instead of being addressed directly to Washington, been sent through the regular exchange channels of the countries from which they emanated, there would have been no difficulty in their prompt and safe arrival at their destinations. Packages of exchanges which are forwarded through the authorized exchange agencies are addressed to the Smithsonian Institution in care of the collector of customs at the port of New York, where they are entered free of duty and forwarded at once to the Institution for distribution through the International Exchanges.

In order to prevent a recurrence of the sale of such material, so far as the Smithsonian Institution and the Library of Congress are concerned, the Institution addressed a letter to the Secretary of the Treasury asking that similar instructions to those given the collector of customs at New York in 1862 and repeated in 1897 be also issued to all the custom-houses in the United States. I am gratified to say that a reply was received stating that instructions to this effect would at once be given to the collectors of all the principal ports. The collectors have also been directed to send to the Smithsonian Institution, as soon as printed, catalogues of all auction sales in the future. A close

supervision will be kept over such sales in the hope of aiding offices and bureaus of the Government whose publications may sometimes go astray.

It has been the practice of the International Exchanges to inclose in each package forwarded through its service a card, properly filled out, to be receipted by the consignee and returned to the Institution. The proper preparation and filing of these cards would require the entire time of one clerk, but on account of the inadequate force it has not been possible to keep a clerk solely engaged on these cards. After careful consideration the conclusion was reached that these receipt cards were not absolutely essential to the records of this office. Acknowledgments of consignments sent abroad are received directly from the various exchange bureaus and agencies, which themselves usually obtain some form of receipt on the delivery of packages to their final destinations, while packages sent to domestic addresses are forwarded by registered mail and an acknowledgment received therefor through the post-office. As these acknowledgments were considered sufficient for the information of this office, the practice of inclosing receipt cards in packages was, with your approval, abolished on January 1, 1906. Since this change it has been possible not only to keep abreast of the work in the record room, but one of the clerks in that room has from time to time been assigned to duty in other branches of the service.

Some of the bureaus and others using the exchange service have occasionally in the past included in their transmissions to the Smithsonian Institution packages for addresses outside of the United States. While the Institution has endeavored, in its desire to diffuse knowledge, to send to their destinations all such publications, it was found that the burden was becoming too great to permit of its being continued, and, with your approval, a circular letter was sent out stating that on account of the great increase in the volume of work the Institution would in the future be compelled to limit the use of the exchange service by correspondents abroad solely to the forwarding of packages for addresses in the United States and territory subject to its jurisdiction. While this change will reduce the total number of packages received from abroad, it will not affect the returns to correspondents in this country.

The International Exchanges was established primarily for the forwarding of books and other printed matter. It has, however, been the practice of the Smithsonian Institution to occasionally grant permission to correspondents to send small packages of specimens for transmission through the service. Requests for the transmission of specimens have of late become more and more frequent, and, in view of the original intention in the establishment of the Exchanges, it was thought that it would be necessary in order not to divert the use of the moneys received for carrying on the service to refuse altogether to send specimens. However, having in mind the damage likely to occur to such valuable scientific material if transmitted through ordinary channels, it was decided that the Smithsonian Institution, in the interests of science, would continue to forward small packages of specimens, making, at the same time, a charge for such transmissions at the rate of 8 cents per pound for botanical specimens and 5 cents per pound for all others.

While it is not expected that any appreciable revenue will be derived from this source, the amounts received will refund the Institution for a part of the expenses connected with such consignments. This charge, it should be remarked, is to apply only to correspondents in the United States and territory subject to its jurisdiction and in those countries where the Institution has its own paid agents. Transmissions of specimens from the Institution are distributed without question by the various exchange bureaus abroad,

and the same courtesy will, of course, continue to be extended to them in the forwarding of such specimens as they may send to the Institution for correspondents in this country.

With the exception of packages for correspondents in the county of London and those for all other places in Great Britain weighing 1 pound or less, the agents of the Institution have, in accordance with long-standing instructions, charged for the forwarding of exchanges from London to destination. It seemed proper, however, that if the Institution undertook the delivery of exchanges at all it should be entirely without cost to the recipients, and in the future all exchanges sent to Great Britain will be delivered to correspondents free of expense. A part of the money which will be saved as a result of the changes referred to in preceding paragraphs of this report will be required for carrying into effect this improvement in the service. This additional charge upon the resources of the International Exchanges will, however, I trust, only be of a temporary nature, as steps have recently been taken to cause the British Government to enter into exchange relations with the United States and establish a bureau of its own. Such a bureau, if established, would take charge of the entire exchange work now conducted by the Smithsonian agency in London, thereby relieving the Institution of the burden of carrying on this work single handed with Great Britain.

The number of complaints of delays in the transmission of packages is becoming more and more infrequent. In every such case during the past year special efforts have been made to trace the cause of the delay, with a view to overcoming it in the future if possible. It should be added that delays in the transmission of exchanges do not, as a rule, occur in the service at Washington nor in the offices of its agents in London, Leipzig, or Budapest, but are due principally to the manner in which some of the exchange bureaus in other countries are conducted—in some instances consignments remaining at such bureaus for a great length of time before their contents are distributed. It may be stated in this connection that there is practically no delay in the distribution of exchanges after their arrival in Washington, packages being immediately recorded and forwarded to their destination by registered mail under the official frank of this Government.

In forwarding consignments to South and Central American countries it is necessary that bills of lading be certified to by the consuls of the various countries. In view of the nature of the contents of the consignments from the Smithsonian Institution—consisting, as they do, of contributions gratuitously presented and not, therefore, representing a commercial transaction—most of the consuls perform this service free of cost to the Institution, while some make a charge of about $2 in each instance. An effort is being made to have such fees waived.

Requests from correspondents of the International Exchanges for publications issued by other establishments than the Smithsonian Institution have become so numerous that all such applicants have during the latter part of the year been uniformly requested to apply directly to the source of publication for such books as they may desire. When it is considered that there are over 50,000 correspondents of the Exchanges, it will be appreciated that it is quite impossible for the service to undertake the solicitation of contributions. It is furthermore provided in the Brussels exchange convention of 1886 that the various bureaus shall not take the initiative to bring about the establishment of exchanges.

In a recent issue of the circular of rules governing the transmission of exchanges a note was added that the Institution does not solicit contributions for its correspondents.

The office collection of directories of large and important cities, catalogues of universities and colleges, and other address books was always given special attention by the late Secretary Langley, and it has been endeavored during the year to make the sectional library in the International Exchanges as complete in this regard as possible.

In accordance with your instructions, all copy for printing for the Exchanges has been submitted to the Secretary's office for approval. The printing in connection with the Exchanges is confined almost exclusively to letter heads and such blank forms as are required in the work of the service, the only publication being the International Exchange List. This list is not issued frequently, the last edition having been published in September, 1903.

The expenses of the International Exchanges are met in part by direct appropriation by Congress and in part by appropriations made to Government departments and bureaus, either in the contingent funds or in specific terms for payment to the Smithsonian Institution of a portion of the cost of the transportation of packages. To each of the departments or bureaus sending or receiving publications through the Smithsonian Institution a charge of 5 cents per pound weight is made under the authority of a resolution of the Board of Regents passed in 1878, this charge being necessary to prevent an undue tax upon the resources of the Institution, as the appropriations made by Congress directly to the Institution for the support of the International Exchanges have never been sufficient to meet the entire cost of the work. For similar reasons it has been found necessary to make a charge of the same amount to State institutions.

The amount appropriated by Congress for the expenses of the service during the fiscal year 1906 was $28,800, an apparent increase over the preceding year of $1,800. This additional amount, however, was transferred from the appropriation for the Library of Congress and is to cover the salaries of two persons employed at the Smithsonian Institution in connection with exchange work for that Library. The sum collected on account of repayments during the year was $5,676.85, making the total amount available for carrying on the Exchanges $34,476.85.

In this connection it should be stated that while $1,000 was added to the Exchange appropriation for 1905 in lieu of the payments which have been made to the Smithsonian Institution for forwarding the publications of the United States Geological Survey, the actual charge for such sendings at 5 cents per pound would have amounted during the past year to $4,535.05. The Smithsonian Institution therefore received for carrying on the Exchanges $3,535.05 less than it would have under the arrangement that existed heretofore. Attention is called to this matter here as it may be considered advisable to bring the facts before the Appropriations Committee during the coming session of Congress with a view to having an additional amount added to the Exchange appropriation.

The number of packages handled during the past year was 171,883, an increase over the number for the preceding year of 6,130. The total weight of these packages was 471,559 pounds, a decrease from 1905 of 3,312 pounds. This decrease is probably due to the reduction of the matter printed by the Government Departments, whose publications constitute about 67 per cent of the weight of all exchange transmissions.

New correspondents in every part of the world are constantly being added to the exchange list, so that they now reach a total of 56,314, an increase of 4,434 over those of the preceding year. These correspondents are subdivided as follows: Foreign institutions, 14,620; foreign individuals, 30,471; domestic in-

stitutions, 3,773, and domestic individuals, 7,450. These correspondents should not be considered as participating in an exchange with the Smithsonian Institution itself, but are the beneficiaries of the facilities of the international exchange service at home and abroad.

The following table gives the number of correspondents in each country, and also serves to illustrate the scope of the service:

Number of correspondents of the International Exchange Service in each country on June 30, 1906.

Country.	Correspondents. Libraries.	Individuals.	Total.	Country.	Correspondents. Libraries.	Individuals.	Total.
AFRICA.				AMERICA (NORTH)—con.			
Algeria	27	51	78	Central America—Con.			
Angola	1	1	2	Nicaragua	20	55	75
Ashantee		1	1	Salvador	22	15	37
Azores	7	16	23	Greenland	3		3
Beira		1	1	Mexico	181	265	446
British Central Africa	2	3	5	Newfoundland	18	37	55
British East Africa	1	4	5	St. Pierre-Miquelon	2	2	4
Canary Islands	2	8	10	United States	3,773	7,450	11,223
Cape Colony	64	116	180	West Indies:			
Cape Verde Islands		5	5	Anguilla		1	1
Egypt	47	105	152	Antigua	8	6	14
French Kongo		2	2	Bahamas	4	14	18
Gambia		1	1	Barbados	11	27	38
German East Africa	5		5	Bermuda	6	28	34
Gold Coast	1	4	5	Bonaire		1	1
Kongo		5	5	Cuba	74	149	223
Lagos	2	7	9	Curaçao	3	7	10
Liberia	3	11	14	Dominica	2	7	9
Lourenço Marquez	1	5	6	Green Turtle Cay		1	1
Madagascar	6	10	16	Grenada	3	6	9
Madeira	3	4	7	Guadeloupe	2	6	8
Mauritius	11	12	23	Haiti	38	21	59
Morocco		15	15	Jamaica	20	51	71
Mozambique		1	1	Martinique		3	3
Natal	22	31	53	Montserrat		2	2
Orange River Colony	3	5	8	Nevis		1	1
Réunion	4	2	6	Porto Rico	10	36	46
Rhodesia	11	15	26	St. Bartholomew		2	2
St. Helena	3	2	5	St. Christopher	2	7	9
Senegal	1	5	6	St. Croix	1	4	5
Sierra Leone	2	3	5	St. Eustatius		1	1
Sudan	1		1	St. Lucia	2	5	7
Transvaal	35	52	87	St. Martin		2	2
Tunis	8	6	14	St. Thomas	2	8	10
Zanzibar	2	5	7	St. Vincent	1	2	3
AMERICA (NORTH).				Santo Domingo	4		4
Canada	394	700	1,094	Tobago		2	2
Central America:				Trinidad	16	16	32
British Honduras	6	15	21	Turks Islands	3	5	8
Costa Rica	30	52	82	AMERICA (SOUTH).			
Guatemala	44	75	119	Argentina	166	271	437
Honduras	14	43	57	Bolivia	23	21	44

Number of correspondents of the International Exchange Service in each country on June 30, 1906—Continued.

Country.	Correspondents. Libraries.	Individuals.	Total.
AMERICA (SOUTH)—con.			
Brazil	159	229	388
British Guiana	20	16	36
Chile	102	129	231
Colombia	40	63	103
Dutch Guiana	5	4	9
Ecuador	27	34	61
Falkland Islands	....	6	6
French Guiana	1	2	3
Panama	4	23	27
Paraguay	21	16	37
Peru	54	99	153
Uruguay	56	47	103
Venezuela	43	57	100
ASIA.			
Arabia	....	7	7
Baluchistan	....	1	1
Burma	14	8	22
Ceylon	32	27	59
China	54	158	212
Cyprus	4	4	8
French India	1	1	2
Hongkong	13	31	44
India	299	364	663
Indo-China	10	11	21
Japan	212	545	757
Korea	4	18	22
Macao	1	....	1
Malaysia:			
Borneo	....	1	1
British New Guinea	....	6	6
British North Borneo	1	2	3
Celebes	....	3	3
Java	24	41	65
New Guinea	....	1	1
Philippine Islands	26	39	65
Sarawak	1	....	1
Sumatra	1	12	13
Persia	3	11	14
Portuguese India	1	....	1
Siam	10	26	36
Straits Settlements	19	25	44
AUSTRALASIA.			
New South Wales	92	221	313
New Zealand	98	152	250
Queensland	54	76	130
AUSTRALASIA—con.			
South Australia	46	87	133
Tasmania	26	35	61
Victoria	120	198	318
Western Australia	36	46	82
EUROPE.			
Austria-Hungary	810	1,585	2,395
Belgium	416	625	1,041
Bulgaria	15	24	39
Denmark	124	274	398
France	1,920	3,800	5,720
Germany	2,689	5,775	8,464
Gibraltar	1	7	8
Great Britain	2,354	7,470	9,824
Greece	43	64	107
Iceland	25	12	37
Italy	937	1,400	2,337
Luxemburg	14	10	24
Malta	13	17	30
Montenegro	2	1	3
Netherlands	235	450	685
Norway	145	239	384
Portugal	115	112	227
Roumania	44	89	133
Russia	576	1,263	1,839
Servia	22	18	40
Spain	224	335	559
Sweden	203	490	693
Switzerland	409	823	1,232
Turkey	53	110	163
POLYNESIA.			
Fiji Islands	2	12	14
German New Guinea	1	....	1
Guam	....	1	1
Hawaiian Islands	32	81	113
Marshall Islands	....	5	5
New Caledonia	....	2	2
New Hebrides	1	....	1
Samoa	6	....	6
Seychelles Islands	....	1	1
Tahiti	....	8	8
Tonga	3	....	3
International	42	....	42
Total	18,393	37,921	56,314

EXCHANGE OF GOVERNMENT DOCUMENTS.

The table which follows exhibits the incoming and outgoing exchanges for the various branches of the United States Government during the year. By

comparison with the last report it will be observed that there was an increase over the present year of 6,368 packages received from abroad for United States Government institutions, while the number of packages sent abroad by this Government was only 1,808 more than during last year. As the total number of packages received from other countries is by no means as large as those sent by the United States, it is most gratifying to note this substantial increase in the fruits of the exchange system to our Government establishments.

Statement of United States Government exchanges during the year 1905–6.

Name of Bureau.	Packages.	
	Received for—	Sent by—
American Historical Association	23	19
Astrophysical Observatory	19	....
Auditor for the State and other Departments	....	524
Bureau of American Ethnology	303	1,316
Bureau of American Republics	27	7
Bureau of Animal Industry	....	1
Bureau of the Census	67	1,298
Bureau of Corporations	2	2
Bureau of Education	109	3
Bureau of Equipment, Navy Department	1	....
Bureau of Fisheries	111	879
Bureau of Foreign Commerce	1	....
Bureau of Insular Affairs	....	6
Bureau of Labor	71	1,013
Bureau of Manufactures	18	6,319
Bureau of the Mint	5	192
Bureau of Navigation, Navy Department	7	....
Bureau of Navigation, Department of Commerce and Labor	....	46
Bureau of Public Health and Marine-Hospital Service	....	553
Bureau of Statistics, Department of Commerce and Labor	151	5,862
Bureau of Steam Engineering, Navy Department	1	....
Civil Service Commission	7	8
Coast and Geodetic Survey	163	420
Commissioner of Internal Revenue	....	14
Commissioners of the District of Columbia	5	53
Comptroller of the Currency	6	172
Custom-House	....	6
Department of Agriculture	527	1,159
Department of Commerce and Labor	10	1
Department of the Interior	20	311
Department of Justice	3	....
Department of State	13	....
Engineer School of Application	2	....
Entomological Commission	4	....
General Land Office	4	....
Geological Survey	696	5,788
Hydrographic Office	49	232
Hygienic Laboratory	1	....
Interstate Commerce Commission	29	827
Library of Congress	18,598	27,393
Life-Saving Service	2	69
Light-House Board	....	181
Military Secretary's Office	....	3
National Academy of Sciences	116	470
National Bureau of Standards	22	....
National Herbarium	3	....
National Museum	664	706
National Zoological Park	1	....
Nautical Almanac Office	36	43
Naval Observatory	162	824
Navy Department	18	....
Office of the Chief of Engineers	33	3
Office of the Chief of Staff, U. S. Army	....	120
Office of Indian Affairs	3	....
Ordnance Office, War Department	2	1
Patent Office	241	1,175
Post-Office Department	1	....
President of the United States	4	....
Smithsonian Institution	4,081	7,684
Superintendent of Documents	1	29
Surgeon-General's Office	128	325
Treasury Department	11	....
War Department	55	23
Weather Bureau	128	918
Total	26,768	67,028

RELATIVE INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

The following is a statement of exchange transmissions by packages between the United States and other countries during the year 1906:

Statement of packages received for transmission through the International Exchange Service during the fiscal year ending June 30, 1906.

Country.	1906. Packages. For—	1906. Packages. From—	Country.	1906. Packages. For—	1906. Packages. From—
Algeria	145	54	Fiji Islands	22	
Angola	3	0	France	10,518	4,507
Antigua	29	0	French Cochin China	30	0
Arabia	29	0	German East Africa	0	1
Argentina	2,558	495	Germany	18,245	6,642
Austria-Hungary	5,584	3,054	Gibraltar	13	0
Azores	28	0	Gold Coast	11	0
Bahamas	39	0	Goree Dakar	8	5
Barbados	89	0	Grenada	9	0
Basutoland	1	0	Great Britain and Ireland	18,000	24,447
Beira	13	0	Greece	786	0
Belgium	3,279	3,295	Greenland	17	0
Bermudas	46	0	Guadeloupe	12	0
Bismarck Archipelago	4	0	Guatemala	232	0
Bolivia	150	0	Guinea	6	0
Bomba	3	0	Haiti	539	0
Bonaire	3	0	Hawaiian Islands	108	4
Borneo	8	0	Honduras	187	0
Brazil	1,841	1,218	Hongkong	117	0
British America	5,167	2,063	Iceland	60	0
British Burma	21	0	India	2,035	89
British East Africa	7	0	Italy	5,805	2,121
British Central Africa	4	0	Jamaica	231	0
British Guiana	83	0	Japan	2,653	65
British Honduras	46	0	Java	230	129
Bulgaria	153	2	Kamerun	1	0
Canary Islands	23	0	Kongo	1	0
Cape Colony	1,050	17	Korea	47	0
Celebes	3	0	Lagos	10	0
Ceylon	222	18	Liberia	63	0
Chile	1,385	55	Lourenço Marquez	279	5
China	531	33	Luxemburg	67	3
Colombia	707	0	Macao	1	0
Costa Rica	849	0	Madagascar	20	0
Cuba	787	372	Madeira	16	0
Curaçao	22	0	Malta	77	0
Cyprus	11	0	Martinique	13	0
Dar-es-Salaam	2	0	Mauritius	61	0
Denmark	1,274	190	Mexico	2,087	2,182
Dominica	51	0	Mombaso	3	0
Dutch Guiana	25	0	Montenegro	2	0
Ecuador	162	0	Morocco	6	0
Egypt	324	5	Mozambique	1	0
Falkland Islands	13	0	Natal	193	0

Statement of packages received from transmission through the International Exchange Service during the fiscal year ending June 30, 1906—Continued.

Country.	1906. Packages. For—	From—	Country.	1906. Packages. For—	From—
Netherlands	2,337	906	Samoa	26	0
Newfoundland	134	0	San Salvador	195	0
New South Wales	2,023	641	Santo Domingo	25	0
New Zealand	1,043	1	Sarawak	2	0
Nicaragua	219	0	Servia	78	86
Norfolk Islands	11	0	Siam	194	0
Norway	1,427	882	Sierra Leone	15	0
Orange River Colony	92	0	Society Islands	14	0
Panama	72	0	South Australia	993	218
Paraguay	152	0	Spain	1,764	174
Persia	42	0	Straits Settlements	150	0
Peru	1,019	196	Sumatra	12	0
Philippine Islands	267	601	Sweden	2,164	39
Porto Rico	14	0	Switzerland	2,861	1,537
Portugal	1,028	155	Tahiti	1	0
Queensland	952	18	Tasmania	674	2
Reunion	10	0	Transvaal	708	1
Rhodesia	33	0	Trinidad	73	0
Roumania	321	16	Tunis	30	5
Russia	4,351	1,620	Turkey	803	0
St. Croix	1	0	Turks Islands	17	0
St. Helena	21	0	United States	50,802	113,419
St. Kitts	16	0	Uruguay	1,310	52
St. Lucia	2	0	Venezuela	727	28
St. Martin	13	0	Victoria	1,934	102
St. Pierre and Miquelon	14	0	Western Australia	747	113
St. Thomas	13	0	Zanzibar	13	0
St. Vincent	2	0			

Consignments are now sent directly to five different establishments in Argentina. As this procedure is contrary to the practice of the International Exchanges in the case of other countries, and as the freight charges connected with the forwarding of exchanges to so many depositories in one country is more than the funds at the disposal of the Institution for carrying on the service will bear, the Department of State has been asked to ascertain through the proper authorities of the Argentine Government whether the National Museum at Buenos Ayres—the one to whom the largest number of sendings are made—can not be designated to act in the future, as it did some years ago, as the official exchange intermediary between Argentina and the United States. It is not expected that there will be any difficulty in effecting this improvement in the service, as Argentina in 1889 adhered to the Brussels convention, which provides, among other things, for the establishment in each of the contracting States of a bureau charged with the duty of conducting the exchanges. Should this change be consummated there will be a material saving to the International Exchanges in the cost of transmissions to Argentina, and at the same time more frequent shipments will be rendered possible.

It is gratifying to state that the long-pending exchange negotiations with China have, through the efforts of the Hon. W. W. Rockhill, American minister

at Peking, finally been brought to a successful conclusion. The Chinese Government has designated the Shanghai bureau of foreign affairs as its representative for this purpose. While this arrangement is only for the exchange of official publications, it is hoped that full exchange relations will be entered into by China in the near future. Pending the arrangement of details the first shipment of Government documents from the United States has not yet been made.

Owing to the death of Dr. Paul Leverkühn, who since 1900 attended to the reception and distribution of exchanges for Bulgaria, all transmissions to that country have been suspended for the present. Doctor Leverkühn was director of the scientific institutions and library of His Royal Highness the Prince of Bulgaria, and this office is now in correspondence with that establishment with a view to enlisting its services in the distribution of exchanges. It should be added that Doctor Leverkühn during his connection with the Smithsonian Institution was of much service in furthering the interchange of publications between Bulgaria and the United States.

As referred to elsewhere in this report, the office of agent of the Institution for Hungary became vacant in the latter part of June through the death of Dr. Joseph von Körösy. Dr. Julius Pikler, who was employed by the Institution as Doctor Körösy's assistant, has been temporarily appointed agent for Hungary, to take effect on July 1, 1906.

Prior to the late Russo-Japanese war packages addressed to correspondents in Korea were distributed through the courtesy of the Russian Commission of International Exchanges at St. Petersburg. In view of the terms of the treaty of peace, the department of foreign affairs at Tokyo—the exchange distributing agency for Japan—was asked to undertake the distribution of such packages as might be received at the Institution for Korean correspondents. It is regretted that the Department was not able, owing to lack of proper arrangements and sufficient funds, to comply with the Institution's wishes in this matter. A number of packages for Korea having accumulated at this office, those that were within the mailing limit were forwarded to their destinations and the remainder were returned to the senders with the statement that there were at present no means of transmitting exchanges to that country. The Korean branch of the Royal Asiatic Society at Seoul has been invited to act as the exchange medium through which packages to and from Korea may be forwarded. No reply has yet been received, though it is hoped that a favorable one will come to hand at an early date.

As a more direct means of transmission, the few packages that are received for Persia, instead of being sent through the Russian Exchange Commission, are now forwarded directly by mail.

All exchanges for Portuguese East Africa have in the past been forwarded through the national library at Lisbon, which acts as the exchange bureau for Portugal and its colonies. As considerable delay in the receipt of packages sent in this manner has been experienced by correspondents in that country, the Institution asked the Government library at Lourenço Marquez to take charge of the reception and distribution of exchanges for Portuguese East Africa. This request the Government library was good enough to comply with.

Following is a list of bureaus or agencies abroad through which the distribution of exchanges is effected. Those in the larger and in many of the smaller countries forward to the Smithsonian Institution reciprocal contributions for distribution in the United States:

Algeria (via France).

Angola (via Portugal).

Argentina: Museo Nacional, Buenos Ayres.

Austria: K. K. Statistische Central-Commission, Vienna.
Azores (via Portugal).
Barbados: Imperial Department of Agriculture, Bridgetown.
Belgium: Service Belge des Échanges Littéraires Internationaux, Brussels.
Bolivia: Oficina Nacional de Inmigracion, Estadística y Propaganda Geográfica.
Brazil: Serviço de Permutaçõs Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
British colonies: Crown Agents for the Colonies, London.[a]
British Guiana: Royal Agricultural and Commercial Society, Georgetown.
Bulgaria (via Germany).
Canada: Sent by mail.
Canary Islands (via Spain).
Cape Colony: Superintendent of the Government Stationery Department, Cape Town.
Chile: Universidad de Chile, Santiago.
China: Zi-ka-wei Observatory, Shanghai.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Minister of Foreign Relations, Quito.
East India: India Store Department, London.
Egypt: Société Khédiviale de Géographie, Cairo.
France: Bureau Français des Échanges Internationaux, Paris.
Friendly Islands: Sent by mail.
Germany: Karl W. Hiersemann, Königsstrasse 3, Leipzig.
Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex street, Strand, London.
Greece: Director of the American School of Classical Studies, Athens.
Greenland (via Denmark).
Guadeloupe (via France).
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea (via Portugal).
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Julius Pikler, "Redoute," Budapest.
Iceland (via Denmark).
Italy: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
Jamaica: Institute of Jamaica, Kingston.
Japan: Foreign Office, Tokyo.
Java (via Netherlands).
Liberia: Care of American Colonization Society, Washington, D. C.
Lourenço Marquez: Government Library, Lourenço Marquez.
Luxemburg (via Germany).
Madagascar (via France).
Madeira (via Portugal).
Mexico: Sent by mail.

---

[a] This method is employed for communicating with a large number of the British colonies with which no means are available for forwarding exchanges direct.

Mozambique (via Portugal).
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.
New Guinea (via Netherlands).
New Hebrides: Sent by mail.
Newfoundland: Sent by mail.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.
Paraguay: Ministerio de Relaciones Exteriores, Asuncion.
Persia: Sent by mail.
Peru: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Exchange Board, Parliament House, Brisbane.
Roumania (via Germany).
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Salvador: Museo Nacional, San Salvador.
Santo Domingo: Sent by mail.
Servia (via Germany).
Siam: Minister for Foreign Affairs, Bangkok.
South Australia: Astronomical Observatory, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instruccion Publica y Bellas Artes, Madrid.
Sumatra (via Netherlands).
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Tasmania: Royal Society of Tasmania, Hobart.
Tunis (via France).
Turkey: American Board of Commissioners for Foreign Missions, Boston.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Zanzibar: Sent by mail.

With the exception of those countries with which the use of the official frank is permitted, the distribution of exchanges to foreign countries was made in 2,065 boxes, 265 of which contained United States Government documents for authorized depositories, and the contents of 1,800 boxes consisted of departmental and scientific and literary publications for miscellaneous correspondents. Of the latter class of exchanges, the number of boxes sent to each country is given below:

Argentina	29	Bolivia	2
Austria	78	Brazil	24
Barbados	3	British colonies	18
Belgium	58	British Guiana	3
Bermuda	2	British Honduras	2

Canada	(a)	New Zealand	12
Cape Colony	13	Nicaragua	4
China	3	Norway	23
Chile	19	Paraguay	5
Colombia	3	Peru	14
Costa Rica	8	Philippine Islands	(a)
Cuba	(a)	Polynesia	(a)
Denmark	13	Porto Rico	(a)
Dutch Guiana	(b)	Portugal	13
East Indies	29	Queensland	9
Ecuador	5	Roumania	(c)
Egypt	5	Russia	68
France and colonies	185	Salvador	4
Germany	301	Santo Domingo	(a)
Great Britain and Ireland	385	Servia	(c)
Greece	3	Siam	9
Guatemala	4	South Australia	12
Haiti	1	Spain	29
Hawaii	(a)	St. Christopher	(a)
Honduras	5	Sweden	51
Hungary	31	Switzerland	45
Italy	87	Syria	3
Jamaica	4	Tasmania	5
Japan	40	Transvaal	5
Liberia	1	Trinidad	2
Mexico	(a)	Turkey	4
Natal	2	Uruguay	12
Newfoundland	(a)	Venezuela	2
New South Wales	31	Victoria	23
Netherlands	40	Western Australia	9

[a] Packages sent by mail.
[b] Included in transmissions to Netherlands.
[c] Included in transmissions to Germany.

The 50 sets of United States official publications provided for exchange purposes by the joint resolution of Congress, approved March 2, 1867, have all been placed in foreign depositories. Finding that a still further exchange with other Governments was necessary in order to increase the collections in the Library of Congress, a joint resolution was approved March 2, 1901, providing 62 sets for distribution abroad in lieu of the 50 sets, as formerly. This resolution also contains a provision for increasing the number of these documents to 100 on the request of the Librarian of Congress. Since the passage of the latter resolution three new depositories have been added to the list of those receiving full sets, a complete statement of which follows:

Argentina: Library of the Foreign Office, Buenos Ayres.
Argentina: Biblioteca Pública Provincial, La Plata.
Australia: Library of the Commonwealth Parliament, Melbourne.
Austria: K. K. Statistische Central-Commission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.

Canada: Parliamentary Library, Ottawa.
Cape Colony: Government Stationery Department, Cape Town.
Chile: Biblioteca del Congreso, Santiago.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba: Department of State, Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
England: School of Economics and Political Sciences, London.
France: Bibliothèque Nationale, Paris.
France: Préfecture de la Seine, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Secretary to the Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Foreign Office, Tokyo.
Manitoba: Provincial Library, Winnipeg.
Mexico: Instituto Bibliográfico, Museo Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.
Ontario: Legislative Library, Toronto.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Quebec: Legislative Library, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Oeffentliche Bibliothek, Dresden.
South Australia: Parliamentary Library, Adelaide.
Spain: Depósito de Libros, Cambio Internacional y Biblioteca General del Ministerio de Instrucción Pública y Bellas Artes, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: Government Library, Pretoria.
Turkey: Minister of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Württemberg: Königliche Landesbibliothek, Stuttgart.

In addition to the full set of Government documents, there are now forwarded to provincial and municipal governments 27 partial sets. The depositories of these sets have been designated by the Library of Congress from time to time since the passage of the resolution of March 2, 1901, and have been selected with a view to procuring such publications in return as were especially desired by that Library.

During the year a request was received through diplomatic channels from the Government of Lourenço Marquez for certain official publications of the United States, to be deposited in the Government Library of that province. This request was complied with, and the first shipment was made on December 30, 1905. This is the only addition to the list of depositories of partial sets during the year 1906. In exchange for these documents the authorities of Portuguese East Africa have stated that there would be sent to the United States not only the publications of Lourenço Marquez, but also those of the Province of Mozambique as well as of the different chartered companies.

The complete list of depositories of partial sets is as follows:

Austria-Hungary: Bürgermeister der Haupt- und Residenz-Stadt, Vienna.
Bolivia: United States Minister, La Paz.
British Columbia: Legislative Library, Victoria.
Bulgaria: Minister of Foreign Affairs, Sofia.
Ceylon: United States consul, Colombo.
Egypt: Bibliothèque Khédiviale, Cairo.
Germany: Grossherzogliche Hof-Bibliothek, Darmstadt.
Germany: Senatskommission für die Reichs- und auswärtigen Angelenheiten, Hamburg.
Germany: Foreign Office, Bremen.
Guatemala: Secretary of the Government, Guatemala.
Honduras: Secretary of the Government, Tegucigalpa.
Jamaica: Colonial Secretary, Kingston.
Lourenço Marquez: Government Library, Lourenço Marquez.
Malta: Lieutenant-Governor, Valetta.
Newfoundland: Colonial Secretary, St. Johns.
New Brunswick: Legislative Library, St. John.
Natal: Colonial Governor, Pietermaritzburg.
Nicaragua: Superintendente de Archivos Nacionales, Managua.
Nova Scotia: Legislative Library, Halifax.
Northwest Territories: Government Library, Regina.
Orange River Colony: Government Library, Bloemfontein.
Prince Edward Island: Legislative Library, Charlottetown.
Paraguay: Oficina General de Informaciones y Canjes y Commisaria General de Inmigracion, Asuncion.
Roumania: Academia Romana, Bukharest.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Straits Settlements: Colonial Secretary, Singapore.
Siam: Foreign Office, Bangkok.

The chief clerk of this office, Mr. W. I. Adams, was, on June 12, 1905, temporarily transferred to the Smithsonian Institution as disbursing agent, though the International Exchanges has profited by his experience and advice on numerous occasions.

Mr. F. W. Hodge, who was acting curator of Exchanges since February 1, 1901, terminated his services with this office on June 30, 1905, and resumed his duties in the Bureau of American Ethnology.

Notwithstanding the fact that the work of the Exchanges has increased over last year and the force has been reduced, the business of the office, in all its branches, was up to date at the end of the year, there being no accumulations on hand.

To those correspondents abroad who give their personal attention and doubtless often expend private means in furthering the interests of the International

Exchanges at large, the grateful acknowledgment of the Institution should be accorded.

The appreciation of the Smithsonian Institution and its branches are due to Mr. Charles A. King, deputy collector of the port of New York, for his constant assistance in clearing consignments from abroad for the Institution.

In conclusion, it is my sad duty to record the death of two of the employees of the International Exchanges—one engaged in the office at Washington and the other employed in the service of the Exchanges at Budapest.

Dr. Joseph von Körösy, director of the municipal statistical office of Budapest, who was appointed agent of the Smithsonian Institution for Hungary on October 1, 1897, died June 23 of this year. Doctor Körösy was the first regent of the Institution for Hungary, all exchanges for that country having been previously forwarded through the Leipzig agency. During Doctor Körösy's connection with the Institution he took special interest in furthering the work of the International Exchanges, which has resulted in a material increase in the number of packages received from correspondents in Hungary for addresses in the United States.

Mr. Solomon G. Brown, employed as packer in this office, died on June 24. He was connected with the Smithsonian Institution almost since its foundation in 1846, and he has occupied various positions under the three Secretaries, the duties of which he always discharged with faithfulness and efficiency.

Respectfully submitted.

Cyrus Adler,

Assistant Secretary in Charge of Library and Exchanges.

Mr. Richard Rathbun,

Acting Secretary of the Smithsonian Institution.

Appendix IV.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1906.

The work has been conducted in accordance with a scheme approved by the Secretary June 13, 1905, slight alterations in the expenditures therein proposed being made from time to time as required by the exigencies of the service.

New house for mammals.—This building, which has been under construction for several years, is now practically completed, with the exception of the exterior cages, walks, etc., which are yet to be made. Work on it has been much delayed because of the difficulty of procuring suitable workmen, owing to the great amount of building going on in the city. The amount expended from the appropriation for the year in connection with this building is about $11,500.

Central heating plant.—Since the inception of the park it has been desired to establish a central plant for heating the permanent buildings of the park. It is evident that a considerable annual saving would thus be effected, both in fuel and in the wages of firemen. Funds have been lacking to do this in a thoroughly satisfactory manner, but the matter seemed so urgent that a beginning was made during the present year. Two large boilers were placed in an extension of the temporary shop building, a coal vault was excavated in the adjoining hillside, and conduits were constructed from the boilers to the new house for mammals, to the lion house, and to the temporary bird house. Part of the heating mains was also installed. The cost of the work was about $2,500.

Culvert in the beaver valley.—During heavy rains a large quantity of detritus is carried down the valley that extends from the western entrance of the park to Rock Creek and which is occupied by the great flying cage, the beaver, otter, and other inclosures. This was sometimes sufficient to dam up the little stream that runs down the valley and thus give it sufficient force to carry away the fences and release the animals. In order to avoid this constantly recurring expense for clearing out the beaver dams and removing unsightly material, it was found necessary to build a concrete culvert of considerable capacity directly through the beaver and otter yards. Its total length was 404 feet and its cost $1,800. It is so arranged that during an ordinary flow the water passes into the yards, while flood water is turned into the conduit. It has been found to work satisfactorily, and it should be extended as far up the valley as the flying cage. This would greatly improve this part of the park, as it would prevent the wash of frequent rains, which now disfigures it.

Repairs.—The temporary structures in which the collections were housed when the park was first established are so rapidly deteriorating and becoming

unfit for occupation that a large amount of repairs to buildings and inclosures was necessary during the year. The wire fences used for many of the inclosures are seriously weakened and a general renewal will be necessary during the coming year.

Roadways and footpaths.—These have required somewhat extensive repairs. The steep character of most of the roads makes it difficult to keep any surface material on them. Heavy rains almost invariably wash off the surface layer, leaving the larger stones of the macadam bare and subject to being torn up by the feet of horses and the wheels of carriages. To put the roads in proper condition it will be necessary to expend considerable sums, which can not be spared from the existing appropriation. Much trouble is also experienced with the footpaths. They are usually made, as are the roads, with a base of broken stone and a surface of pulverized limestone. After nearly every rain considerable repairs are required, which constitute an important item of expense. It would doubtless be cheaper in the end to put in at once, on the steeper slopes, properly constructed concrete walks.

The extension of the city streets on the eastern side of the park has occasioned an elevation of the roads, making slopes which are very unsightly and down which a large amount of loose material is washed by rains into the park. In order to preserve the natural beauty of this region it will be necessary to protect the grounds from invasions of this character, both by planting the slopes and by suitably raising the grades in the park.

New survey and map.—The survey of the park, commenced last year, has been extended over about 40 acres more. This work is of great practical utility, and it is hoped to eventually map the entire park in this manner.

Electric lighting.—A local company having extended a conduit for electric lighting as far as the entrance to the park, advantage was taken of this to run wires to the office building and stable, which have never been furnished heretofore with any fixed lights. It may be advisable to light also some of the darker roadways in the park, which are quite tortuous and narrow, and therefore dangerous at night.

Important accessions by gift.—Young male zebra and young male lion from Ras Makonnen, governor of Harrar Province, Abyssinia, who also sent a female zebra and a male oryx antelope, but these latter two died en route.

Polar bear, through W. S. Champ, from Zeigler Polar Relief Expedition.

From Capt. C. E. Radclyffe, Hyde, Wareham, England, 2 red deer.

From R. McM. Gillespie, president Chesapeake Western Railway Company, 3 black bears.

From Hon. E. H. Plumacher, American consul at Maracaibo, Venezuela, several Venezuelan mammals and birds.

Accessions by exchange.—From the New Zealand government, 1 kiwi, 1 kea, 3 flightless rails, and 1 tuatera lizard.

From the department of crown lands, Province of Ontario, Canada, 10 black squirrels.

From the New York Zoological Park, 4 Indian white cranes.

From dealers in animals, 1 Alaskan brown bear, a fine male markhor goat, and several other goats, sheep, and deer.

Births.—The births, 127 in number, include 1 Brazilian tapir, 1 yak, 5 Barbary sheep, 5 wapiti, 2 mule deer, 2 Columbian black-tailed deer, and deer of several other species; also 2 monkeys and several kangaroos, besides a number of wolves, arctic foxes, and other mammals.

The birds in the flying cage nested well and young were hatched by cormorants, white ibis, sandhill cranes, and night herons. The pair of wild turkeys which has the freedom of the park also nested and produced four young.

Important deaths.—Gastro-enteritis was the most prevalent trouble. The number of cases of tuberculosis was comparatively small.

Male tiger. This animal had been in the collection thirteen years and was quite old when received. He had been failing for some months and being unfit for exhibition was finally chloroformed, with the consent of the owner, Mr. J. A. Bailey.

Female tiger, from interstitial nephritis.

Jaguar, female, an old animal, in poor condition when received, from hemorrhagic septicemia.

Grizzly bear, brain showed pathological features in both hemispheres, one side suggesting results of old abscess, but immediate cause of death was not distinctly ascertained by the autopsy.

One sea lion, from gastro-enteritis.

American bison, one calf from gastro-enteritis, and one old male from broken spine.

Two Arabian camels, one from gastro-enteritis, the other from tuberculosis.

One Rocky Mountain sheep, from gastro-enteritis.

Young male zebra, from accident.

One cassowary, from filariasis.

One emu, from gastro-enteritis.

One rhea, from pleuro-pneumonia.

Two Indian white cranes and several other birds, from aspergillosis.

All dead animals which were in fit condition for preservation were transmitted to the National Museum, the number sent during the year being 226. Autopsies were made by pathologists of the Bureau of Animal Industry, who also assisted with sick and diseased animals.

Visitors.—The use of the park by schools and as a place of recreation is steadily increasing. On April 16, 1906, Easter Monday, it was estimated that 28,000 people, mostly children, were on the grounds during the day.

Statement of animal collection.

Accessions during the year:	
Presented	102
Loaned	3
Purchased and collected	118
Received in exchange	87
Born in National Zoological Park	127
Total	437

Cost for purchase, collection, and transportation of above, $3,200.

Animals in the collection.

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	264	167	78	509
Birds	381	218	44	643
Reptiles	117	13		130
Total	762	398	112	1,272

Animals presented during the fiscal year ending June 30, 1906.

Name.	Donor.	Number.
Green monkey	Louis Brandt, Washington, District of Columbia	1
White-throated capuchin	Miss Justine Ingersoll, Jamaica Plain, Boston, Massachusetts.	2
Spider monkey	Hon. E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Lion	Ras Makonnen, governor of Harrar Province, Abyssinia	1
Lynx	A. M. Meyer, Palo Alto, California	1
Gray wolf	Vernon Bailey, Washington, District of Columbia	2
Coyote	do	3
Rough fox	Hon. E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Gray fox	E. C. Conger, Edenton, North Carolina	1
Raccoon	J. A. Herbert, Washington, District of Columbia	1
Do	Frederick Rogers, Washington, District of Columbia	1
Black bear	Robert McM. Gillespie, Harrisonburg, Virginia	3
Do	Miss K., Washington, District of Columbia	2
Polar bear	W. S. Champ, for Ziegler Polar Relief Expedition, New York City.	1
Harbor seal	U. S. Bureau of Fisheries, Washington, District of Columbia.	2
Somali zebra	Ras Makonnen, governor of Harrar Province, Abyssinia	1
Red deer	Capt. C. E. Radclyffe, Hyde, Wareham, Dorset, England	2
Angora goat	Mrs. J. P. McCalmont, Washington, District of Columbia	1
Red squirrel	J. S. Milstead, Newington, Virginia	1
European rabbit	Wm. E. Field, Washington, District of Columbia	2
Do	Josef O. Kordina, of Austrian Embassy, Washington, District of Columbia.	1
Do	Mrs. M. D. Hensey, Washington, District of Columbia	1
Linnet	N. B. Plunket, Washington, District of Columbia	3
Common canary	C. A. Sidman, Washington, District of Columbia	1
American magpie	Mrs. D. T. Day, Washington, District of Columbia	1
Common crow	Nelson R. Wood, Washington, District of Columbia	2
Red and yellow and blue macaw.	F. L. Goll, Washington, District of Columbia	1
Amazon	Mrs. Annie Farley, Washington, District of Columbia	1
Parrakeet	Mrs. Nicholas Longworth, Washington, District of Columbia.	2
Do	Mrs. W. R. Wright, Baltimore, Maryland	1
Great horned owl	Dr. C. M. Buckey, Washington, District of Columbia	1
Red-tailed hawk	G. C. Miley, Winchester, Virginia	1
Do	Fritz S. Nye, Wytheville, Virginia	1
King vulture	Hon. E. H. Plumacher, United States consul, Maracaibo, Venezuela.	1
Ring dove	Mrs. Nicholas Longworth, Washington, District of Columbia.	2
European quail	Charles W. Dimick, Boston, Massachusetts	1
Great blue heron	Adams Express Co., Washington, District of Columbia	1
Canada goose	Mrs. K. E. Kastle, Benning, District of Columbia	4
Mallard	Mrs. K. E. Kastle, Benning, District of Columbia	2
Gannet	William Aldrich, Washington, District of Columbia	1
Alligator	Fred Staffin, Wilmington, North Carolina	12
Do	James Young, Washington, District of Columbia	1
Do	A. De Carre, Washington, District of Columbia	1
Do	Miss Virginia Sanborn, Washington, District of Columbia	2
Do	Donor unknown	4
Do	Mrs. C. S. Haight, Washington, District of Columbia	1
Banded rattlesnake	Mrs. Nicholas Longworth, Washington, District of Columbia.	1
California rattlesnake	George W. Colles, Milwaukee, Wisconsin	3
Prairie rattlesnake	Dr. Cecil French, Washington, District of Columbia	4

Animals presented during the fiscal year ending June 30, 1906—Continued.

Name.	Donor.	Number.
Massasauga	Prof. H. L. Clark, Olivet, Michigan	4
Copperhead	R. G. Paine, Washington, District of Columbia	1
King snake	Jesse Hand, jr., Belleplain, New Jersey	1
Do	H. E. Thomas, Washington, District of Columbia	1
Tree boa	Hon. H. G. Squiers, envoy extraordinary and minister plenipotentiary to Cuba, Habana, Cuba.	1
Fox snake	Prof. E. S. Moseley, Sandusky, Ohio	3
Black snake	H. L. Torreyson, Glen Echo, Maryland	1
Do	W. O. Snelling, Washington, District of Columbia	2

SUMMARY.

Animals on hand July 1, 1905	1,307
Accessions during the year	437
Total	1,744
Deduct loss (by exchange, death, and returning of animals)	472
On hand June 30, 1906	1,272

Respectfully submitted.

FRANK BAKER, *Superintendent.*

Mr. RICHARD RATHBUN,
Acting Secretary of the Smithsonian Institution.

Appendix V.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

Sir: The character and value of property pertaining to the Astrophysical Observatory are approximately as follows:

Buildings	$8, 900
Apparatus	46, 300
Library and records	7, 500

During the past year a small fireproof shelter has been erected in the northeast corner of the Observatory inclosure to contain storage batteries and an alternating-current generator, and to serve as a distributing center for all the electrical currents used for the Observatory. An underground power line has been laid by the electric lighting company to connect the Observatory and the main Smithsonian building directly with the main on B street independently of the National Museum. This fireproof building and power line cost $1,400.

The two shelters occupied in 1905 by the expedition on Mount Wilson have been improved in a manner adapting them to maintain a more uniform temperature, and a tower and third small shelter for cloud reflection experiments have been erected. The total cost for these improvements was $200.

Apparatus for research has been procured at a cost of $1,000, of which $200 was chargeable to the appropriation of 1905–6.

The usual scientific periodicals have been continued, a few books of reference have been purchased, and some periodicals and books have been bound at a total cost for the Observatory library of $60.

No losses of property have occurred.

Personnel.—The Observatory suffered the loss of its distinguished founder and director in the death of Secretary S. P. Langley, on February 27, 1906.

Mr. L. R. Ingersoll served as temporary bolometric assistant from July 1, 1905, to September 8, 1905, and again from June 16, 1906, to July 1, 1906.

Miss F. A. Graves was appointed computer beginning January 10, 1906.

Work of the Observatory.

During the past year the work of the Observatory has been steadily directed with the aim of securing proof of the suspected variability of the sun, but for convenience the year's work will be described under the following classification:

1. Miscellaneous work.
2. Observations at Washington.
3. Observations on Mount Wilson.
4. General statement of results.

MISCELLANEOUS WORK.

Preparation for publication.—The research on a possible variability of the solar radiation has been continued so long and has given promise of leading to results of such definiteness and importance as to justify its publication as

Volume II of Annals of the Astrophysical Observatory. Considerable time has been occupied by the aid acting in charge in the preparation of the text for this volume, which it is hoped to publish during the coming fiscal year.

Computation of results.—The reduction of observations of solar radiation and solar absorption has occupied the main portion of the time of the junior assistant and computer, but without interfering with the continuation in Washington of the series of observations on the absorption of the solar envelope and the solar radiation. Improved methods of reduction have been devised, so that the task of reducing a single day's work is not as heavy as formerly.

Improvements of apparatus.—In earlier reports the principles embodied in a new form of standard pyrheliometer have been set forth. It may be recalled, however, that in this instrument the solar radiation, which passes at right angles through a circular aperture of known area, is principally absorbed at the rear end of a cylindrical hollow chamber, and that such portions of heat or radiation as escape from the rear end of the chamber are absorbed at other points along its walls, so that heat is almost wholly prevented from escaping at the entrance. The heat thus fully absorbed within the chamber is taken up by a current of water which flows steadily at a measured rate in a spiral course round the walls of the chamber, entering at the front and leaving at the rear; and the rise of temperature of the water is determined by a platinum resistance thermometer. Thus the rate of solar radiation is measured by the rise of temperature it produces in a known amount of water. A definite check on the accuracy of the instrument is had by introducing a measured electric current through a coil of wire situated within the chamber, thus producing a known amount of heat there. The agreement between this amount of heat and the amount carried off by the flowing water, as determined by means of the recording apparatus, is the evidence of the excellence of the pyrheliometer. In practice the instrument has now come to a high state of perfection, and forms a valuable part of the equipment on Mount Wilson. Various improvements of the means of promoting a satisfactory circulation of the water and of measuring its rise of temperature have been introduced during the year.

Several copies of an improved form of secondary pyrheliometer have been made at the Observatory shop and added to the equipment. This instrument, though coming by a kind of evolution from Pouillet's water pyrheliometer, has now become very different from it. The receiving surface is a copper disk blackened by smoke. A cylindrical bulb thermometer is inserted radially in a hole at the side of the disk, and its connection with the disk improved by filling the hole with mercury, which is prevented from spilling by packing at the mouth of the hole. A hollow copper sphere incloses the disk, and this is protected from outside temperatures by being inclosed in a wooden sphere. The solar rays pass down a diaphragmed tube and fall at right angles upon the copper disk. When reading the instrument, it is alternately shaded and exposed to the sun at two-minute intervals, and the rate of rise of temperature of the disk is determined from thermometer readings made each twenty seconds. Readings with this instrument must be compared with those of the standard pyrheliometer to reduce them to the absolute scale, but as between themselves the readings appear to be accurate to half of 1 per cent independent of wind or temperature outside.

The bolometer also has received very essential improvements, one of them consisting of a device for abolishing "drift" in situations where it is not possible to maintain the bolometer at uniform temperature. This is done by introducing as a part of one of the balancing coils of the bolometer a little copper wire in place of an equal resistance of wire of zero temperature coeffi-

cient. For a good bolometer only 1 or 2 per cent of the resistance needs to be thus substituted. The improvement obtained on Mount Wilson is so great that the "drift" in a single bolograph now rarely reaches a centimeter, although a rise of temperature of nearly 2 degrees centigrade per hour may be taking place. The bolometric apparatus may be conveniently balanced by the aid of a variable shunt of high resistance round one of the balancing coils. This device is employed now instead of a slide wire for determining the sensitiveness of the platinum thermometer used with the standard pyrheliometer.

Some trial has been made of a new device of entirely different principle, as a rival of the bolometer and its class of instruments. This new instrument is not yet fully perfected, but gives some promise of exceeding in sensitiveness either the bolometer, the thermopile, the radiometer, or the radio-micrometer.

OBSERVATIONS AT WASHINGTON.

Notwithstanding the fact that it has been deemed expedient for the satisfactory proof of the variability or constancy of solar radiation to conduct many of the observations at the favorable station on Mount Wilson, still the observations at Washington remain of hardly less importance than before. For the determination of the amount of solar radiation outside the earth's atmosphere depends so largely on our estimate of the loss by scattering and absorption of the rays in the air that very much of the confidence with which we may hope the work will ultimately be regarded must be produced by the number and weight of the circumstances which tend to establish the accuracy of the estimate of the effect of the earth's atmosphere. Chief in importance among such checks is the simultaneous observation of the sun's radiation at stations remote from one another and different in altitude, like Washington and Mount Wilson. When it is said that the solar radiation received at the earth's surface on Mount Wilson generally exceeds that in Washington by a third, but that, nevertheless, simultaneous spectrobolometric observations at high and low sun at the two places yield substantially identical values of the solar radiation outside the atmosphere, the soundness of the work seems strongly verified. In order to secure as many checks of this kind as possible, solar constant determinations have been made by Mr. Fowle in Washington at all times when the sky conditions warranted. Apparently a very considerable rise of the solar constant values, occurring in January after Mr. Abbot's return from Mount Wilson, was observed at Washington alone. As in former years, the number of days suitable for these observations in Washington has been small.

Another important independent method of securing evidence of the variability of the sun is found in the bolometric examination of the solar image to measure the absorption taking place in the sun's immediate surroundings. This observation depends but little on the clearness of the earth's atmosphere, and can therefore be carried on about as well in Washington as anywhere. As stated in former reports, the Observatory is provided for this work with a horizontal reflecting telescope of 20 inches aperture and 140 feet focus, easily one of the largest telescopes of the world. Observations with the spectrobolometer at the focus of this great telescope have been carried on regularly by Mr. Fowle throughout the year. Improved means for stirring the column of air within the telescope tube to improve definition have been provided, but, requiring additional electrical facilities, their trial was postponed to await the completion of the electric station above referred to.

OBSERVATIONS ON MOUNT WILSON.

The departure of an expedition in charge of Mr. Abbot to Mount Wilson, in California, in May, 1905, and the circumstances which led to its location there in response to the kind invitation of the director of the Carnegie Solar Observatory and the president of the Carnegie Institution were mentioned in last year's report. Observations were continued by the expedition on Mount Wilson until October 27, 1905, when the approach of cold weather and the frequent rise of fog over the mountain made the observing so difficult, especially in the temporary shelter in which the bolometric apparatus was situated, that Mr. Abbot was recalled. By request and invitation of the officials of the Carnegie Institution most of the apparatus was left in place on Mount Wilson, in order to provide in some way for the continuation of solar constant work there during 1906. Later it was determined to renew the Smithsonian expedition, and Mr. Abbot returned about May 5, 1906, and after June 15, 1906, was again aided, as in 1905, by Mr. L. R. Ingersoll, temporary bolometric assistant .

During 1905 the solar constant was observed on Mount Wilson on fifty-six days, depending on about 600 bolographs and about 1,000 pyrheliometer readings. Observations were made on a number of days on the transmission of the solar envelope and in sun spots. Pyrheliometer readings were made on Mount San Antonio (over 10,000 feet high) simultaneous with solar constant determinations on Mount Wilson (6,000 feet high). A few days of observation were devoted to the determination of the reflective power of clouds and the scattering of light by the sky.

In 1906 additional instrumental equipment was provided, and a tower has been erected at the point of a ridge overlooking deep canyons on three sides for use in conducting from its summit careful measurements by the bolometer of the comparative brightness of equal angular areas of cloud and sun at all solar altitudes, and thus to determine what effect clouds have on the total amount of solar radiation available to the earth. Almost ideal conditions for this experiment are often had on Mount Wilson, for a level-topped sea of fog often rises and remains stationary for hours within a few hundred feet of the base of the tower above mentioned. It is also intended to observe the brightness of the sky with the bolometer, making supplementary spectrophotometric eye observations. Solar constant determinations were begun by Mr. Abbot about May 15, 1906, and are being continued almost every day, except when clouds prevent. As regards transparency of sky and freedom from clouds, the conditions in 1906 are much less favorable than they were in 1905 on Mount Wilson. It may be possible that the prolonged eruption of Mount Vesuvius has had a similar effect to that of the great eruption of Krakatoa in 1883 in perturbing the air. It will be interesting to see if the observations of others indicate a general decrease of the transparency of the earth's atmosphere.

GENERAL STATEMENT OF RESULTS.

Reserving for the forthcoming Volume II of the Annals of the Astrophysical Observatory a detailed statement of the results obtained and a discussion of them, the principal results of the year may be summarized as follows:

A. *Agreement between Washington and Mount Wilson solar constant observations.*

So far as the reductions have enabled the results to be compared, there seems to be no difference of a systematic kind between Washington and Mount Wilson spectro-bolometric determinations of the solar radiation outside the earth's atmosphere. The probable error of Mount Wilson determinations is

naturally smaller, owing to the high altitude and clear sky, but the results for the two stations in general agree within 2 or 3 per cent, and thus within the probable error of the Washington observations.

Considering the great difference in altitude of the stations, this tends strongly to increase confidence in the soundness of the method of "solar constant" determination employed.

B. *Absolute value of the "solar constant."*

Preliminary comparisons between the secondary pyrheliometers heretofore used and the standard pyrheliometers now perfected indicate that the preliminary scale of values of the "solar constant" heretofore published in these reports is probably very nearly correct. During the observations in 1905 on Mount Wilson the solar radiation was generally below the mean value of about 2.12 calories as observed at Washington, and averaged about 2.03 calories.

C. *Estimation of the "solar constant" by the pyrheliometer alone.*

As stated in last year's report, Mr. Fowle has found that a fairly close value of the solar radiation outside our atmosphere may be obtained on good days in Washington by making an exponential treatment of high and low sun observations obtained with the pyrheliometer alone and adding 14 per cent to the value reached outside the atmosphere. As was to be expected, the empirical correcting factor is found to be smaller than 14 per cent when the Mount Wilson observations are treated in this manner, and it is also more variable—ranging from 8 to 12 per cent—probably depending on the humidity of the air. Some ten years ago Prof. K. Ångström made observations at high altitudes on the island of Teneriffe with his pyrheliometer. This instrument reads lower than our standard pyrheliometer, so that a correction must be added to his observations to make them comparable with ours. Applying a correction for this cause and reducing Ångström's observations by the exponential method and adding 10 per cent (the mean of the corrections determined on Mount Wilson) we obtain for mean solar distance 2.25 calories for the solar constant during Ångström's Teneriffe experiments of 1895, a value about as much higher than the mean given under B as the Mount Wilson mean value is below it. This value is well below the highest values found by spectrobolometric work at Washington within recent years. Thus the best modern pyrheliometry is not discorded with the view that the "solar constant" is close to 2.12 calories.

D. *Evidence of solar variability.*

In general, the solar constant determinations obtained on Mount Wilson have internal evidence of being of very great weight. For example, the exponential plots of the kind published as Plate VI in my report for the year ending June 30, 1903, often have eight or ten points distributed over a range of air mass three times that which the sun shines through in the zenith, all lying within 1 per cent of the representative straight line. So far as can be seen it appears that the Mount Wilson determinations of solar radiation outside our atmosphere are usually accurate relatively to 1 per cent or better. The observations between June 1 and August 5, 1905, are on the average higher than those between August 5 and October 27. But fluctuations of from 5 to 8 per cent occur repeatedly, and often in periods of about ten days.

Washington observations confirmed the results of September and October, but were lacking in July and August owing to bad observing weather. In December excellent days were had in Washington, indicating low values, but in

January the numbers rose very high, and the results became as high or higher than any before recorded and remained through most of February fully 15 per cent above the Mount Wilson values of late August. After this there was again a falling off, and the Mount Wilson work of May and June, 1906, gives about the same results as the corresponding months of 1905. By anticipation it may be added that July, 1906, does not appear to run parallel to July, 1905, by bringing higher values.

On the whole the solar-radiation work of the past year furnishes the strongest evidence of solar variability yet recorded by this Observatory.

E. *Confirmatory indications of solar variability.*

While lack of knowledge of the conditions surrounding the sun makes conclusions drawn from a study of the apparent absorption of the solar envelope doubtful, still the following inferences seem to be reasonable. If the solar envelope should decrease in transmissibility, the solar radiation ought at first to diminish, but after a time the radiating substance behind the absorbing envelope should increase in temperature, owing to the obstruction of its radiation by the absorbing envelope, so that at length the solar radiation should reach nearly its former value despite the greater absorption in the envelope. Similarly a falling off in solar absorption should immediately produce increased radiation and afterwards a decrease of radiation.

The observations of the solar image made at Washington and Mount Wilson in the past fiscal year are not yet so completely reduced as to be profitably compared with the observations of solar radiation on the basis of this hypothesis. But it may be noted that during the month of July, while solar radiation appeared to be increasing, the transparency of the solar envelope appeared to be increasing also, which is in accordance with expectation. Furthermore, the values representing the solar transmission at this time were below the mean values for several years, which also accord with expectation.

Lack of knowledge of the local conditions which govern the earth's temperature prevents us from making at the present time accurate forecasts of the effect of a variation of the sun on the earth's climate. Thus, for example, a decrease of solar radiation may cause in some localities a decrease of cloudiness sufficient to allow as much sunlight to reach the earth as came before the fall of solar radiation took place. For the world in general, however, it might naturally be expected that a decrease of solar radiation would cause a fall of the earth's temperature. It is therefore in accordance with expectation that the summer and early winter of 1905 were cooler than the average, while in January and February, 1906, there was uncommon mildness, followed by a cool spring.

SUMMARY.

The work of the Astrophysical Observatory for the year has principally consisted in the continuation at Washington and on Mount Wilson of researches designed to discover any variability of solar radiation. The results of the year's work have furnished the strongest evidence yet secured that the solar radiation reaching the limits of the earth's atmosphere varies frequently and notably in amount. According to present information, the mean value of the solar constant of radiation is not far from 2.12 calories per square centimeter per minute; its range of fluctuation is irregular and sometimes reaches 15 per cent, and its periods of fluctuation are variable.

C. G. Abbot,
Acting Director Astrophysical Observatory.

Mr. Richard Rathbun,
Acting Secretary of the Smithsonian Institution

Appendix VI.

REPORT ON THE LIBRARY.

Sir: I have the honor to present the following report on the operations of the library of the Smithsonian Institution for the fiscal year ending June 30, 1906:

There have been recorded as accessions to the Smithsonian deposit in the Library of Congress 1,754 volumes, 14,192 parts of volumes, 4,250 pamphlets, and 522 charts, making a total of 20,718 publications; extending the accession numbers from 468,087 to 475,178. A few of these publications have been held, being immediately necessary for reference in connection with the scientific work of the Institution, but the greater part was sent direct to the Library of Congress. The publications sent to the Library of Congress were transmitted in 293 boxes, and are estimated to have amounted to an equivalent of 11,720 volumes, exclusive of public documents presented to the Institution and forwarded to the Library of Congress at once without stamping or recording, as well as public documents or other gifts to the Library of Congress received through the International Exchange Service.

The selecting and sending to the Library of Congress of volumes and parts of volumes that had been held for the use of the staff in the past years have been continued as far as the current work would allow.

The libraries of the Secretary, Office Astrophysical Observatory, and National Zoological Park have received 542 volumes, pamphlets, and charts, and 1,832 parts of volumes, making a total of 2,374, and a grand total, including books for the Smithsonian deposit and the Watts de Peyster Collection, of 24,326.

The parts of serial publications that were entered on the card catalogue numbered 25,666. One thousand five hundred and fifty-seven slips for completed volumes were made, and 600 cards for new periodicals and annuals were added to the permanent record from the periodical recording desk.

Inaugural dissertations and academic publications were received from universities at the following places:

Baltimore (Johns Hopkins).
Basel.
Bern.
Breslau.
Erlangen.
Freiburg.
Giessen.
Greifswald.
Halle a. S.
Heidelberg.
Helsingfors.
Ithaca (Cornell).
Jena.
Jurjew (Dorpat).
Kazan.
Kiel.
Leipzig.
Marburg.
New York (Columbia).
Paris.
Rostock.
St. Petersburg.
Toulouse.
Tubingen.
Utrecht.
Washington, D. C. (Catholic University of America).
Wurtzburg.
Zurich.

In carrying out the plan to effect new exchanges and to secure missing parts to complete sets, 1,541 letters were written, resulting in 287 new periodicals being added to the receipts, while 631 defective series were partly or entirely completed. In addition to the letters referred to, 99 postal cards were mailed and 73 missing parts were received in response.

As a result of a suggestion of the Librarian of Congress, it was decided that reprints of articles in periodicals or transactions and circulars, etc., ephemeral in nature and purpose, would be retained at the Institution.

The plan adopted by the International Catalogue of Scientific Literature of sending to authors lists of their scientific writings that have been indexed in the Catalogue, and requesting any that have not been cited, has proven of special benefit to the library of the Institution, as a number of separates on American material have been added in this way.

In the reference room 201 volumes of the transactions and proceedings of learned societies were withdrawn, and from the reading room 25 bound volumes of periodicals and 3,885 parts of scientific periodicals and popular magazines were borrowed. The use of these publications and those in the sectional libraries of the Institution by persons from other bureaus of the Government has been continued, but in the main the consultation has been by members of the staff.

The mail receipts numbered 34,716 packages, the publications contained therein being stamped and distributed for entry from the mail desk. Four thousand eight hundred acknowledgments were made on the regular form, exclusive of those for publications received in response to the requests of the Institution for exchange.

There has been no change in the number of the sectional libraries maintained in the Institution, they being the Secretary's library, office library, and the employee's library, together with those of the Astrophysical Observatory, aerodromics, international exchanges, and law reference.

At the request of the Aero Club of America the Smithsonian Institution exhibited in the aeronautical section of the automobile show, held in New York City, 43 volumes of publications on aeronautics from the section of aerodromics.

The current periodicals in the Astrophysical Observatory have been collated, missing numbers secured, and 38 volumes were bound. The library at the National Zoological Park had an addition of 19 volumes and 25 pamphlets, which were received by gift and purchase.

The employee's library.—The number of books borrowed from the employee's library was 1,216, and the sending of a selected number of the books from this library to the National Zoological Park and the Bureau of American Ethnology each month continues to be appreciated.

The John Donnell Smith library.—While this library is still in the possession of Mr. John Donnell Smith, a book plate has been provided and under the direction of Mr. Smith copies have been placed in each of the volumes, about 1,700 in number, so that their identification, when they are finally forwarded to the Institution, may be complete.

The Watts de Peyster collection.—Through the continued munificence of Gen. John Watts de Peyster, the Watts de Peyster collection has received an addition of 1,234 volumes.

Tibetan manuscript.—Early in the year a unique Tibetan manuscript, entitled "Prajna Paramita," i. e., Transcendental Wisdom, was received as a gift from the government of India. It is written in gold characters on black ground of 366 cardboards, which are held between two covers of lacquered wood, and

was collected by Lieutenant-Colonel Waddell, archæologist of the Indian government expedition to Tibet in 1904–5, during this expedition. The height is 10 inches; width, 17½ inches; thickness, 7 inches.

The art room.—The collection of prints and art publications in the art room has been thoroughly reexamined. A tentative arrangement has been made of the prints which are now being catalogued, they having been placed in paper folders and made ready for permanent arrangement. The serial publications are being collated and prepared for binding when the opportunity offers.

The Museum library.—The National Museum library has been exceptionally fortunate in gifts this year, having received the following valuable donations:

A copy of the magnificent publication Investigations and Studies in Jade, in two volumes, profusely illustrated by American, European, and Chinese artists, from the estate of the late Heber R. Bishop. Mr. Bishop, who donated his large collection of jades and other hard stones to the Metropolitan Museum of Art, of the city of New York, gave much of his time for many years to the preparation of a treatise on jade and a catalogue illustrating his collection. The publication of the work was left to his executors and the number of copies was limited to 100, to be distributed to members of his family, heads of governments, and the principal libraries and museums having libraries in this and other countries; the United States National Museum was included in the distribution.

Prof. Lester F. Ward, for many years connected with the Museum in an honorary capacity, presented his collection of paleobotanical and botanical books, pamphlets, and memoirs of all kinds that were in the National Museum building. Mr. Robert Ridgway, curator of birds, presented a collection of publications consisting of a large number of separates on natural history and a complete set of the Proceedings of the United States National Museum, and Dr. Charles W. Richmond, assistant curator of the same division, has given a series of valuable works, numbering over 100, on natural history and travel. Prof. O. T. Mason and Dr. C. A. White have continued to add to their collections presented some years ago, and many valuable publications have come to the library in this way.

In the Museum library there are now 27,726 volumes, 44,075 unbound papers, and 108 manuscripts. The additions during the year consisted of 3,556 books, 5,327 pamphlets, and 105 parts of volumes. There were catalogued 1,848 books, of which 136 belonged to the Smithsonian deposit, and 4,864 pamphlets, of which 116 belonged to the Smithsonian deposit, and 12,228 parts of periodicals, of which 640 belonged to the Smithsonian deposit. In the accession book 3,556 volumes, 5,327 pamphlets, and 105 parts of volumes were recorded. The number of cards added to the catalogue was 8,439.

In connection with the entering of periodicals memoranda were made reporting volumes and parts missing in the sets, together with a few titles of publications that were not represented in the library. The result of this work was the completing or partial filling up of 40 sets of periodicals.

Attention has been given to the preparation of volumes for binding, with the result that 290 books were sent to the Government bindery.

The number of books, periodicals, and pamphlets borrowed from the general library amounted to 28,924, including 19,354, which were assigned to the sectional libraries. This does not include, however, the large number of books consulted in the library but not withdrawn.

The sectional libraries established in the Museum have remained the same, the complete list now standing as follows:

Administration.	Geology.	Parasites.
Administrative assistant.	History.	Photography.
Anthropology.	Insects.	Physical anthropology.
Biology.	Mammals.	Prehistoric archæology.
Birds.	Marine invertebrates.	Reptiles.
Botany.	Materia medica.	Stratigraphic paleontology.
Children's room.	Mesozoic fossils.	Superintendent.
Comparative anatomy.	Mineralogy.	Taxidermy.
Editor.	Mollusks.	Technology.
Ethnology.	Oriental archæology.	
Fishes.	Paleobotany.	

SUMMARY.

In the following table are summarized all of the accessions during the year for the Smithsonian deposit, for the libraries of the Secretary, office, Astrophysical Observatory, United States National Museum, and National Zoological Park. That of the Bureau of American Ethnology is not included, as it is separately administered:

Smithsonian deposit in Library of Congress	20, 718
Secretary, office, and Astrophysical Observatory libraries	2, 374
Watts de Peyster collection	1, 234
United States National Museum library	8, 988
National Zoological Park	44
Total	33, 358

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The Smithsonian Institution continued during the fiscal year ending June 30, 1906, the preparation of the International Catalogue of Scientific Literature in cooperation with other countries of the world.

There were sent from here during the year 25,601 classified citations to American scientific literature, as follows:

Literature of 1901	301
Literature of 1902	622
Literature of 1903	3, 538
Literature of 1904	12, 139
Literature of 1905	9, 001
Total	25, 601

During the present fiscal year 22 volumes have been published and distributed to the subscribers in this country, as follows:

Second Annual Issue: Zoology. (Completing the issue.)

Third Annual Issue: Geography, General Biology, Physiology, Geology, Paleontology, Human Anatomy, Chemistry, Mineralogy, Meteorology, Botany, Physical Anthropology, and Zoology.

Fourth Annual Issue: Astronomy, Mathematics, Bacteriology, Mechanics, Geology, Paleontology, Physics, and Mineralogy.

The first meeting of the International Convention of the International Catalogue of Scientific Literature was held in London July 25 26, 1905, there being

present one or more delegates from each of the following named countries: Austria, Belgium, France, Germany, Greece, Holland, India, Italy, Japan, Mexico, Russia, South Africa, United Kingdom, and the United States of America, whose delegate, appointed by the Smithsonian Institution, was Dr. Leonhard Stejneger, of the United States National Museum.

In the International Convention is vested the supreme control of the Catalogue, and in the beginning of the undertaking it was agreed that its meetings should be held in 1905, 1910, and thereafter every ten years. At the meeting in 1905 the convention was expected to pass judgment on the value and importance of the project and on the advisability of continuing the work beyond the first period of five years, which will end with the publication of the volumes for 1905. Another important subject before the convention was that of reviewing and, if necessary, revising the classification schedules as originally agreed on. Regarding the first question it was unanimously resolved:

"That in view of the success already achieved by the International Catalogue of Scientific Literature, and of its great importance to scientific workers, it is imperative to continue the publication of the Catalogue at least for a further period of five years."

The classification schedules were referred to a committee, who, after having met and considered all suggestions from the various bureaus throughout the world, decided to continue the general methods in use up to that time, though making many minor changes in the schedules. Some additions were required to fill omissions in the original schedules, and others also were necessary to provide suitable places for the numerous scientific subjects which had developed since the beginning of the enterprise.

The zoological section of the Catalogue, through an understanding with the Zoological Society of London, will become amalgamated with the Zoological Record, which has been for years the standard zoological yearbook. By this method the International Catalogue gains the services of some of the foremost zoologists in the world.

All of the references to zoology collected by the various regional bureaus of the catalogue throughout the world will be submitted for approval to the experts of the Zoological Society, who, in the future as in the past, will be in charge of the Zoological Record, which, beginning with the literature of 1906, will be published as the zoology volume of the International Catalogue.

Early in 1901 the actual work of preparing the International Catalogue of Scientific Literature was begun, and during and since that time the Smithsonian Institution has felt obliged to allot each year a sum of money from its own limited funds to carry on the work in this country. The Institution has each year felt that even the small sum set apart for the work was a serious drain on its resources, and each year the hope was entertained that Congress would make a suitable appropriation for carrying on the work on behalf of the United States.

At a meeting of the Board of Regents on January 24, 1906, it was decided to approach Congress in the hope of obtaining financial aid. By the authority thus given the Institution took the necessary steps to bring the matter to the attention of Congress, with the result that an item was inserted in the sundry civil bill worded as follows:

"International Catalogue of Scientific Literature: For the cooperation of the United States in the work of the International Catalogue of Scientific Literature, including the preparation of a classified index catalogue of American scientific publications for incorporation in the International Catalogue, the expense of clerk hire, the purchase of necessary books and periodicals, and other

necessary incidental expenses, $5,000, the same to be expended under the direction of the Secretary of the Smithsonian Institution."

In concluding this report I can not but refer to the loss which the library of the Institution shares with the entire establishment in the death of the Secretary, Mr. S. P. Langley. His first services in connection with the Institution were, in considerable measure, devoted to its library during the term of his office as Assistant Secretary. Later, as Secretary, he reorganized the library system, bringing together in one centralized administration the libraries of the Institution and Museum and of the other branches of the Institution, with the single exception of the Bureau of Ethnology. No one used the library more constantly than did the late Secretary, and no one observed its rules so faithfully. He was interested in every class of literature that came here and in all the departments of library work. Not only the general plan for the carrying on and increase of the library, but all of its details were known to him, and he made constant suggestions for the improvement of the work and repeated inquiries as to its progress.

Under his administration the quarters assigned to the library were multiplied many times, and his interest in the members of the staff led him to establish a general reading room for those who were not strictly connected with the scientific work; and also later he established a sort of circulating library, which even had a traveling section for the benefit of the employees of the National Zoological Park and the Bureau of Ethnology. He greatly promoted bibliographical work, both in the matter of publication as well as in the support which he gave to the International Catalogue of Scientific Literature.

The Secretary was a daily donor to the library, since he made it a rule to present to it, with a few trifling exceptions, all of the valuable scientific works which were given him, either in exchange for his own publications or because of his distinguished position in the scientific world.

I can not but feel that the library, more than the other branches of the Smithsonian work, has met with an irreparable loss in his passing away, for joined with his eminence as an original investigator he was essentially a book man and had a profound and direct interest in everything relating to the book world—scientific, historical, and literary.

Respectfully submitted.

Cyrus Adler,

Assistant Secretary in Charge of Library and Exchanges.

Mr. Richard Rathbun,

Acting Secretary of the Smithsonian Institution.

Appendix VII.

REPORT ON THE PUBLICATIONS.

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its bureaus during the year ending June 30, 1906:

I. *Smithsonian Contributions to Knowledge.*

In the series of Smithsonian Contributions to Knowledge the following memoir, which was in press at the close of the last fiscal year, has been published:

1651. A Continuous Record of Atmospheric Nucleation. By Carl Barus. City of Washington; published by the Smithsonian Institution. 1905. (Hodgkins Fund. Part of Vol. XXIV, Smithsonian Contributions to Knowledge.) Quarto. Pages xvi, 226.

II. *Smithsonian Miscellaneous Collections.*

To the series of Smithsonian Miscellaneous Collections the following numbers have been added:

1585. Smithsonian Miscellaneous Collections (Part of Vol. XLVIII). Quarterly Issue, Vol. III, part 2. City of Washington; published by the Smithsonian Institution, 1905. 8vo. Pages 117–240, plates xxxiv–lviii.

1587. The History of the Whale Shark (Rhinodon typicus Smith). By Barton A. Bean. (Quarterly issue.) 8vo. Pages 139–148, plates xxxiv–xxxvi.

1588. The Avian Genus Bleder Bonaparte and Some of its Allies. By Harry C. Oberholser. (Quarterly issue.) 8vo. Pages 149–172.

1589. Scaphoceros tyrelli, an Extinct Ruminant from the Klondike Gravels. By Wilfred H. Osgood. (Quarterly issue.) 8vo. Pages 173–185, plates xxxvii–xlii.

1590. A New Genus and Several New Species of Land Shells Collected in Central Mexico by Dr. Edward Palmer. By William Healey Dall. (Quarterly issue.) 8vo. Pages 187–194, plates xliii–xliv.

1591. The Family of Cyprinids and the Carp as its Type. By Theodore Gill. (Quarterly issue.) 8vo. Pages 195–217, plates xlv–lviii.

1592. The International Catalogue of Scientific Literature. By Cyrus Adler. (Quarterly issue.) 8vo. Pages 219–221.

1593. Instances of Hermaphroditism in Crayfishes. By William Perry Hay. (Quarterly issue.) 8vo. Pages 222–228.

1594. Notes to Quarterly Issue, Vol. III, part 2, pages 229–240.

III. *Smithsonian Annual Report.*

The Annual Report for 1904 was mostly in type on June 30, 1905, but the edition was not printed and distributed until October. The contents of the volume were enumerated in the last report of the editor.

The general appendix of the report for 1905 was transmitted to the Public Printer toward the close of the fiscal year. The Secretary's report on the operations of the Institution, which forms part of the Regents' report to Congress, was printed December 1, 1905, in a pamphlet of 96 pages:

1654. Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1905. Washington: Government Printing Office, 1905. 8 vo. Pages 1–96 with plates I–VII.

The general appendix of the 1905 volume will contain the following papers:

New Measurements of the Distance of the Sun, by A. R. Hinks.
Photographing Lightning with a Moving Camera, by Alex Larsen.
The Tantalum Lamp, by W. Von Bolton and O. Fuerlein.
Some Refinements of Mechanical Science, by Ambrose Swasey.
Progress in Radiography, by L. Gastine.
History of Photography, by Robert Hunt.
The Genesis of the Diamond, by Gardiner F. Williams.
The Cullinan Diamond, by F. H. Hatch and G. S. Corstorphine.
Gold in Science and in Industry, by G. T. Beilby.
Submarine Navigation, by Sir William H. White.
Liberia, by Sir Harry Johnston.
The Geographical Results of the Tibet Mission, by Sir Frank Younghusband.
The Development of Rhodesia and its Railway System in Relation to Oceanic Highways, by J. T. P. Heatley.
The Ethics of Japan, by Baron Kencho Suyematsu.
Plague in India, by Charles Creighton.
The Fight against Yellow Fever, by A. Dastre.
Luminosity of Plants, by Prof. Hans Molisch.
Notes on the Victoria Lyre-Bird, by A. E. Kitson.
The Influence of Physical Conditions in the Genesis of Species, by Joel A. Allen.
Parental Care among Fresh-water Fishes, by Theodore Gill.
On the Relations between the United States and Germany, especially in the Field of Science, by Herr Wilhelm Waldeyer.
Walter Reed, by Walter D. McCaw.
Rudolph Albert von Kolliker, by William Stirling.

IV. *Publications of United States National Museum.*

The publications of the National Museum are: (a) The Annual Report, forming a separate volume of the Report of the Smithsonian Institution; (b) The Proceedings of the United States National Museum; (c) The Bulletin of the United States National Museum.

There were issued during the year the Annual Report of the Museum for 1904; volumes 28, 29, and 30 of the Proceedings; Bulletins 54 and 55, the former on the Isopod Crustaceans of North America, the latter on the Oceanography of the Pacific Ocean; and Part 1 of Volume X of Contributions from the National Herbarium, the latter work being included in the Bulletin series.

The full bibliography of the above publications will be given in the Annual Report on the National Museum.

V. *Publications of the Bureau of American Ethnology.*

The twenty-third annual report of the Bureau of American Ethnology was published in December, 1905, and progress was made on the twenty-fourth report. The twenty-fifth report was transmitted to the printer during the year,

while the twenty-sixth report was retained by the Bureau until the completion of the two preceding volumes.

Bulletin 28 was published in October and Bulletin 29 in December. The composition and most of the press work of the first volume of Bulletin 30 was completed during the year, and the manuscripts of Bulletins 31 and 32 were transmitted to the Public Printer.

VI. *Report of the American Historical Association.*

The annual report of the American Historical Association for the year 1905 was received from the association and transmitted to the Public Printer in May, 1906. Its contents are as follows:

Report of Proceedings of the Twenty-first Meeting at Baltimore and Washington, December 26–29, 1905, by Charles H. Haskins, corresponding secretary.
Old Standards of Public Morals, by John Bach McMaster.
Virginia and the English Commercial System, 1730–1733, by St. George L. Sioussat.
Why North Carolina at First Refused to Ratify the Federal Constitution, by Charles Lee Raper.
The First Lord Baltimore and His Colonial Projects, by Bernard C. Steiner.
The Authorship of the Monroe Doctrine, by James Schouler.
Report of Conference on Teaching of History in Elementary Schools, by J. A. James.
Report of Conference on First Year of College Work in History, by Charles H. Haskins.
Second Report of Conference of State and Local Historical Societies, by F. H. Severance.
Report of Proceedings of Second Annual Meeting of Pacific Coast Branch of the American Historical Association, by C. A. Duniway.
Slavery in California after 1848, by C. A. Duniway.
Origin of the National Land System under the Confederation, by P. J. Treat.
Report on Method of Organization and Work of State and Local Historical Societies, by Thwaites, Shambaugh, and Riley.
Report of the Public Archives Commission.
Bibliography of American Historical Societies, by A. P. C. Griffin.

VII. *Report of the Daughters of the American Revolution.*

The eighth report of the National Society of the Daughters of the American Revolution was received from the society in June, and was submitted to Congress in accordance with the requirements of the law.

Respectfully submitted.

A. Howard Clark, *Editor.*

Mr. Richard Rathbun,
Acting Secretary of the Smithsonian Institution.

Appendix VIII.

REPORT ON THE LEWIS AND CLARK CENTENNIAL EXPOSITION, PORTLAND, OREGON, 1905.

Sir: I have the honor to submit the following report on the exhibit of the Smithsonian Institution and National Museum at the Lewis and Clark Centennial Exposition held at Portland, Oregon, from June 1 to October 14, 1905, inclusive:

An act of Congress approved April 13, 1904, provided for a Government exhibit to be made by the several Executive Departments, bureaus, and other organizations, including the Smithsonian Institution and National Museum, under the management of a Government board. The sum of $200,000 was appropriated for this exhibit, another appropriation of $25,000 was authorized for an exhibit by the district of Alaska, and $250,000 was appropriated for the construction of suitable buildings.

The main Government building was located on an islandlike peninsula in the lake included in the exposition grounds. This peninsula was connected with the main portion of the exhibition grounds by the "Bridge of Nations," which was about one-third of a mile in length. Adjoining the main building on the south, and connected with it by a colonnade, was a smaller building for the exhibits of the Bureau of Fisheries of the Department of Commerce and Labor; while a similar building was on the north side, containing the exhibits of Alaska and the Philippine Islands. Behind the latter was another and smaller building containing irrigation and forestry exhibits.

The total floor space of the Government building and its annexes was about 80,000 square feet. The portion in the Government building assigned to the Smithsonian Institution and National Museum, comprising about 5,000 square feet, was located in the rear of the building and had no frontage on the main aisle, but was divided into two unequal parts by a secondary aisle.

In accordance with the intent of the law, the Government exhibit consisted chiefly of portions of the exhibits made at the Louisiana Purchase Exposition during the preceding year. The plans formulated for the exhibits of the Smithsonian Institution and its bureaus were entirely along the lines laid down at the St. Louis Exposition, although the choice of specimens required considerable care, as the space allotted to the Institution and the National Museum was only about one-third of the area of the space assigned to them at the Louisiana Purchase Exposition.

SMITHSONIAN INSTITUTION PROPER.

This exhibit, which was placed against the west wall of the Smithsonian space, comprised pictures of James Smithson, founder of the Institution, a facsimile of his will, a cast of the bronze tablet placed on his tomb at Genoa, Italy, and views of the tomb itself, and a photograph of the mortuary chapel in the Smithsonian Institution where Smithson's remains now rest; photo-

graphic portraits of the Regents, the Chancellors, and the Secretaries of the Institution; papers and medals relating to the Hodgkins fund; a complete set of the publications of the Institution; an enlarged photograph of the Smithsonian seal, and pictures of the Smithsonian and Museum buildings.

INTERNATIONAL EXCHANGES.

The International Exchange Service exhibited a statistical chart showing its operations from its founding up to 1904 and photographs of its offices, all of which objects were hung on the western portion of north wall.

ASTROPHYSICAL OBSERVATORY.

The Observatory showed several large charts illustrating the results of its investigations upon solar radiation, the most conspicuous of which was that of the infra-red spectrum. All were placed on the western portion of the north wall, together with transparencies representing solar eclipses, sun spots, etc.

NATIONAL ZOOLOGICAL PARK.

Just to the west of the north door were shown enlarged photographic views of some of the animals living in the park and of the animal houses and paddocks, together with a model of the park, and maps showing details of the park and its location in the city of Washington.

BUREAU OF AMERICAN ETHNOLOGY.

This exhibit, representing the researches of one of the ethnologists of the Bureau, consisted of a series of 55 models and 2 originals of shields and 8 models of tepees of the Kiowa Indians, illustrative of many of their beliefs and customs. This exhibit was placed in the west section of the wall case.

UNITED STATES NATIONAL MUSEUM.

I. *Department of Anthropology.*

The exhibit of this department of the Museum was installed in the west section of the Smithsonian space. It comprised reproductions, on a reduced scale, of five of the temples, or palaces, built by the Indians of the ancient civilizations of Mexico and Yucatan. The structures shown were: "Temple of the Cross" at Palenque, the "Castle" at Chitzen-Itza, the "Governor's Palace" at Uxmal, the "Temple of Xochicalco," and a temple at Mitla. Photographs, plans, and diagrams of these and other ruins were shown separately, as well as some full-size details of the temples.

II. *Department of Geology.*

This exhibit, which was placed in the central portion of the Smithsonian space, embraced:

1. A systematic collection of minerals, represented by unusually large specimens.

2. An exhibit of meteorites, which comprised, (a) plaster casts of three meteorites collected by Commander Peary, U. S. Navy, in north Greenland, the largest one being the greatest mass ever known to have fallen from the sky;

(b) a plaster cast of the Bacubirito meteorite in Mexico, another remarkably large piece of nickel-iron; (c) a plaster cast of the Ainsa-Irwin, or Tucson (Arizona) meteorite, in the form of a ring of iron, the original of which is in the National Museum; (d) a map showing the location of known meteorite falls in the United States; (e) pictures of falling meteorites, or "shooting stars," and photographs showing the internal structure of stony, iron, and stony-iron meteorites.

3. Representations of some interesting fossil vertebrates of North America, which comprised: (a) Life-sized restoration of the armored dinosaur, *Stegosaurus ungulatus*, showing the supposed external appearance of the animal, based on remains in the National Museum; (b) natural-sized restoration of the skeleton of the three-horned dinosaur, *Triceratops prorsus*, from the original in the National Museum. On the wall was hung an oil painting representing the external appearance of this great reptile in its native surroundings; (c) pictures showing skeletons or restorations of other dinosaurs, of an icthyosaur, of a pterydactyle (or flying reptile), and of an extinct toothed diving bird.

III. *Department of Biology.*

This department, situated at the east end of the Smithsonian space, showed:

1. A nearly complete skeleton of the dodo, *Didus ineptus*, an extinct flightless bird of the island of Mauritius. A few living birds were brought to Holland in the sixteenth century, and from these at least four different pictures were painted by various artists. One of the best of these, a life-sized profile, is in the British Museum, and an exact reproduction of it was hung near the skeleton.

2. A complete skeleton (made up from bones of many individuals) of the great auk, *Plautus impennis*. A cast of its egg and a natural-sized photograph of the mounted specimen in the National Museum were also exhibited.

3. A collection of birds' eggs from all parts of the world, including eggs of common birds, bright-colored eggs, eggs of the humming-bird, the smallest, and a cast of the largest egg known, that of the *Æpyornis*, an extinct bird of Madagascar.

4. A series of bright-colored pheasants of the Old World, together with a pair each of three species of peacocks.

5. A mounted American alligator and an American crocodile, placed opposite one another in order to show clearly the differences between these two largest existing American reptiles.

6. A group of large game animals of Europe, Asia, and Africa: Chamois, Norway elk, moufflon, Manchurian tiger, Marco Poло sheep, axis deer, Sambur stag, lion, and rhinoceros. In addition to these, mounted heads of the nilghi, greater and lesser kudus, Jackson's hartebeeste, beisa antelope, and ibex, and antlers of the American elk and caribou were hung on the walls.

7. At various places on the walls of the Smithsonian exhibit-space were placed plates taken from Audubon's work on North American birds, among them one of the great auk. Another series of pictures comprised photographs showing the making of a cast of a sulphur bottom whale at Balena Station, Newfoundland.

8. Suspended over the center of the Smithsonian space was a skeleton of an adult little piked whale, *Balænoptera acuto-rostrata*.

Dr. F. W. True was representative for the Smithsonian Institution and National Museum on the Government board. Dr. M. W. Lyon, jr., was chief special agent.

Summary of allotment made to the Smithsonian Institution and National Museum.

Original allotment	$13,000.00
Transfer to Philippine Island exhibit	342.00
Total	12,658.00

Classified statement of expenditures of funds allotted to the Smithsonian Institution and National Museum.

Services of clerks, mechanics, and laborers, and care of exhibits	$5,263.47
Transportation of persons	1,388.25
Per diems in lieu of subsistence	721.49
Freight, cartage, and expressage	1,619.33
Cases, material only	6.25
Packing materials	81.54
Miscellaneous supplies (stationery, office furniture, janitors' supplies, etc.)	477.40
Specimens and construction of exhibits, including materials, services, etc.:	
National Museum	1,058.43
Other bureaus of the Institution	14.60
Total expenditure	10,630.76
Unexpended balance	2,027.24
Net allotment	12,658.00

Respectfully submitted.

F. W. True,
Representative of the Smithsonian Institution and United States National Museum, Lewis and Clark Centennial Exposition.

Mr. Richard Rathbun,
Acting Secretary of the Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1906

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1906.

THE SMITHSONIAN INSTITUTION.

The Smithsonian Institution is an establishment at Washington, founded by act of Congress approved August 10, 1846, in accordance with a bequest of James Smithson, an Englishman, "for the increase and diffusion of knowledge among men." The act creates, in effect, a museum, a library, a gallery of art, laboratories, lectures, and provides for such other methods as might further the promotion of knowledge, these having later been construed to include publications, explorations, researches on the part of the staff of the Institution, and aids to research by supplying apparatus and making grants to investigators elsewhere. The Smithson bequest, with accumulated interest, now amounts to $650,000, to which has been added gifts and bequests, notably those of Thomas G. Hodgkins, of $215,918.69, making the total Smithsonian fund in the United States Treasury at the present time $944,918.69. Upon this fund, and up to $1,000,000, the United States has agreed to pay in perpetuity interest at the rate of 6 per cent per annum. Other investments bring the capital of the Institution up to about $1,000,000. All of the operations of the Institution proper must be carried on with the income of this very limited fund.

The Institution is by law an Establishment composed of the President of the United States, the Vice-President, the Chief Justice, and the heads of the Executive Departments. It is governed by a Board of Regents, consisting of the Vice-President and Chief Justice, ex officio, three members of the Senate, appointed by the President of the Senate, three members of the House of Representatives, appointed by the Speaker of the House, and six citizens of the United States, appointed by act of Congress, two of whom are residents of the city of Washington and four of States of the Union, but no two of the same State. The Secretary of the Establishment and of the Board of Regents is the Secretary of the Institution and director of its activities.

The Regents have usually been selected from among the most distinguished Members of Congress and the citizen Regents from among the presidents of great universities or eminent public men.

The Institution has had four Secretaries: Joseph Henry, 1846 to 1878, physicist and discoverer of the electro-magnet; Spencer Fullerton Baird, 1878 to 1887, naturalist and founder of the United States Fish Commission; Samuel Pierpont Langley, 1887 to 1906, astronomer and astrophysicist and discoverer of the laws of mechanical flight, which he successfully demonstrated; and Charles Doolittle Walcott, elected 1907, paleontologist and geologist.

The activities of the Institution fall under the following heads: (1) The Institution proper; (2) the National Museum; (3) the International Exchanges; (4) the Bureau of American Ethnology; (5) the National Zoological Park; (6) the Astrophysical Observatory.

The Institution has aided numerous investigators with advice, direction, and money, supplying books, apparatus, and laboratory accommodations. It has also conducted series of public lectures, which have afterwards been published. It undertook the collection of meteorological data for weather forecasting and prepared the first daily weather map ever issued in the world. Its work in this field, after being brought beyond the experimental stage, was transferred to the Signal Service of the United States Army, and afterwards resulted in the establishment of the United States Weather Bureau. It likewise undertook the initial investigations on the food-fishes of the country, which resulted in the establishment of the United States Fish Commission, now the Bureau of Fisheries.

Publications of great value have been issued in the following series:

Annual reports, 1846 to 1905, containing numerous papers of general interest intended to keep the ordinary reader abreast of the progress of science.

Smithsonian Contributions to Knowledge, of which 32 volumes have appeared, the distinguishing feature of which is that each memoir constitutes an original contribution to knowledge.

Miscellaneous Collections, of which 48 volumes have been printed. These contain bibliographies, reports of expeditions, standard tables, and minor scientific papers. Since 1902 some of the papers of this series have been issued in the form of a scientific Quarterly.

Under the Hodgkins foundation, a portion of which was intended for the increase and diffusion of knowledge in regard to atmospheric air and its relation to the welfare of man, numerous investigations have been undertaken and medals and prizes awarded, the most notable being a prize of \$10,000 to Lord Rayleigh and Sir William Ramsay for their discovery of the element "Argon" in the atmosphere.

One of the important features of the Institution is the library, numbering over 250,000 volumes, consisting mainly of transactions of learned societies and scientific periodicals, secured initially by purchase, but now regularly added to by way of exchanges with numerous universities and other institutions at home and abroad. Since 1866 the main portion of this library has been deposited in the Library of Congress, thus enriching the national collections. A small working library has been brought together in the Institution. Library methods and scientific bibliography have been greatly furthered by the Institution, and many valuable lists and bibliographies and rules for cataloguing have been published. Since 1901 the Institution has acted on the part of the United States as one of the component bureaus of an International Catalogue of Scientific Literature, with headquarters at London, which prepares and issues annual volumes of indexes to the literature of natural and physical sciences.

The Institution has for a number of years supported a table in the biological station at Naples, to which qualified investigators are admitted free of cost to them.

THE NATIONAL MUSEUM.

The Smithsonian Institution is the custodian, and the only lawful place of deposit, of all objects of art and of foreign and curious research, and all objects of natural history, plants, and geological and mineralogical specimens belonging to the United States. These collections are popularly known as the National Museum. The history of the Museum is divided into three periods, first, from the foundation of the Smithsonian Institution to 1857, during which time specimens were collected solely to serve as materials for research; second, from 1857 (when the Institution assumed the custody of the "National Cabinet of Curiosities") to 1876, during which period the Museum became the place of deposit for scientific material which had already been studied by investigators and had become available for public exhibition and educational purposes. In 1876 the Museum entered upon a new career of activity as a result of the large collections secured by the Government and the Institution after the close of the Centennial Exposition at Philadelphia, and Congress provided a new building, which was erected upon the Smithsonian grounds and opened to the public in 1881. In 1903 an additional building, at a cost of $3,500,000, was provided for and is now in course of erection.

The collections of the Museum are especially rich in the natural history, geology, paleontology, archeology, and ethnology of America, and also include many other subjects, such as American history, ethnography, and collections relating to fine art and the industrial

arts. The Museum is both an educational and research institution, the exhibition series being specially well arranged and labeled from an educational point of view, while the study series form the working basis for numerous investigations both on the part of the Museum staff and by many scientific men in the United States and abroad. In furtherance of its work, the Museum has issued numerous reports, bulletins, and proceedings, which contain many valuable reports of research as well as contributions to knowledge.

Gallery of art.—One of the fundamental objects prescribed by the act of Congress founding the Institution was the establishment of a Gallery of Art, a portion of the Smithsonian building being especially designed for this purpose. The building itself is a fine example of architectual art during the latter half of the twelfth century, variously styled Norman, Romanesque, or Lombard, and its erection was made possible by funds accumulated as interest on the Smithson bequest. In 1849 a very valuable collection of etchings and engravings belonging to George P. Marsh was purchased and a gallery was maintained until 1865, when the prints and engravings were deposited in the Library of Congress, and later the other art collections were deposited in the Corcoran Gallery of Art. These, however, were in the main recalled from both places in 1896 and reexhibited at the Institution. In 1906 Charles L. Freer conveyed to the Institution his valuable art collections, including many paintings by Whistler and four other American artists, numerous etchings and engravings by Whistler, and many examples of Chinese and Japanese art, as well as a large collection of oriental pottery. In the same year, as the result of a judicial decision, the Institution was declared in law and in fact to be the National Gallery of Art, thereby securing the small but choice art collection of Harriet Lane Johnston, including examples of the greatest English portrait painters, and a number of historical objects.

In March, 1907, the National Gallery was further enriched by the gift of Mr. William T. Evans, of Montclair, N. J., who presented to it 50 paintings representing the best of the work of American artists. These paintings are now on exhibition in the large atrium of the Corcoran Gallery of Art, through the courtesy of its directors, until a suitable place shall be provided for them in the Smithsonian Institution.

The Museum was under the direct charge of Spencer F. Baird, as Assistant Secretary of the Institution, from 1850 to 1878, when he became Secretary, and he was largely aided in its management by George Brown Goode, who served as Assistant Secretary in charge of the Museum from 1887 to 1896. He was succeeded by Charles D. Walcott, 1896 to 1898, and by Richard Rathbun, 1898 to date.

THE INTERNATIONAL EXCHANGES.

A system of International Exchanges was begun in 1850 for the free interchange of scientific publications between institutions and investigators in the United States and those in foreign lands. In 1867 Congress assigned to the Institution the duty of exchanging 50 copies of all public documents of this country for similar documents of foreign nations, and this number was in 1901 increased to 100 sets at the option of the Librarian of Congress. In 1889 a definite treaty, made previously at a convention at Brussels, was formally proclaimed by the President of the United States, wherein the United States Government with a number of others undertook the continuation of the exchange service on a more extensive basis. Out of this has grown the Bureau of International Exchanges, for the maintenance of which Congress provides by annual appropriation. The total number of correspondents benefited by this service is 56,314, and from 1850 to 1906, 2,748,852 packages were handled by it. The Exchange service is in charge of an Assistant Secretary, Cyrus Adler.

THE BUREAU OF AMERICAN ETHNOLOGY.

The Bureau of American Ethnology is an outgrowth of researches beginning early in the history of the Institution, which has, from the outset, devoted much attention to the study of the tribes of American Indians. It took its present form through Congressional appropriation in 1879, and has collected a large amount of data relating to the habits and customs, the laws, the religions, the languages, and the physical characteristics of the aborigines of this continent. It has published 25 reports and 31 bulletins, and has a great amount of unpublished material, including hundreds of vocabularies. Besides doing a considerable amount of archeological work, it has made important additions to knowledge, and also invaluable collections. The Director of the Bureau of American Ethnology, from its inception to 1902, was Maj. J. W. Powell, who has been succeeded as chief by W. H. Holmes.

ASTROPHYSICAL OBSERVATORY.

The Astrophysical Observatory was established in 1890 and has been under the immediate direction of Mr. S. P. Langley, who here continued researches previously begun at the Allegheny Observatory. These investigations of solar radiations made possible by Mr. Langley's invention of the bolometer, have resulted in the production of a complete map by an automatic and absolutely trustworthy process which shows at the unknown region or invisible spectrum the lines

that resemble the so-called Fraunhofer lines in the upper spectrum. The study has been especially directed to that region of the spectrum which includes the greater portion of all those energies of the sun which affects, through its heat, the climate and the crop. Its present director is C. G. Abbot.

NATIONAL ZOOLOGICAL PARK.

The National Zoological Park was established by Congress in 1890 for the advancement of science and the instruction and recreation of the people, and incidentally to secure the preservation of such American animals as were upon the verge of extinction. The park is situated on Rock Creek, 2 miles north of the center of Washington, and has an area of 167 acres. It is amply supplied with water, and its surface is of a varied and picturesque character. The collections comprise about 1,400 animals. The park is in charge of a superintendent, Frank Baker.

MODERN THEORIES OF ELECTRICITY AND MATTER.[a]

By Madame Curie, *Chargé de cours à la Sorbonne.*[b]

When one reviews the progress made in the department of physics within the last ten years, he is struck by the change which has taken place in the fundamental ideas concerning the nature of electricity and matter. The change has been brought about in part by researches on the electric conductivity of gas, and in part by the discovery and study of the phenomena of radioactivity. It is, I believe, far from being finished, and we may well be sanguine of future developments. One point which appears to-day to be definitely settled is a view of atomic structure of electricity, which goes to confirm and complete the idea that we have long held regarding the atomic structure of matter, which constitutes the basis of chemical theories.

At the same time that the existence of electric atoms, indivisible by our present means of research, appears to be established with certainty, the important properties of these atoms are also shown. The atoms of negative electricity which we call electrons, are found to exist in a free state, independent of all material atoms, and not having any properties in common with them. In this state they possess certain dimensions in space, and are endowed with a certain inertia, which has suggested the idea of attributing to them a corresponding mass.

Experiments have shown that their dimensions are very small compared with those of material molecules, and that their mass is only a small fraction, not exceeding one one-thousandth of the mass of an atom of hydrogen. They show also that if these atoms can exist isolated, they may also exist in all ordinary matter, and may be in certain cases emitted by a substance such as a metal without its properties being changed in a manner appreciable by us.

If, then, we consider the electrons as a form of matter, we are led

[a] Translated, by permission, from Révue Scientifique, Paris, 5e Série, Nos. 20, 21, vol. VI, November 17 and 24, 1906.

[b] Opening lecture of the course in general physics delivered at the Sorbonne, November 5, 1906.

to put the division of them beyond atoms and to admit the existence of a kind of extremely small particles, able to enter into the composition of atoms, but not necessarily by their departure involving atomic destruction. Looking at it in this light, we are led to consider every atom as a complicated structure, and this supposition is rendered probable by the complexity of the emission spectra which characterize the different atoms. We have thus a conception sufficiently exact of the atoms of negative electricity.

It is not the same for positive electricity, for a great dissimilarity appears to exist between the two electricities. Positive electricity appears always to be found in connection with material atoms, and we have no reason, thus far, to believe that they can be separated. Our knowledge relative to matter is also increased by an important fact. A new property of matter has been discovered which has received the name of radioactivity. Radioactivity is the property which the atoms of certain substances possess of shooting off particles, some of which have a mass comparable to that of the atoms themselves, while the others are the electrons. This property, which uranium and thorium possess in a slight degree, has led to the discovery of a new chemical element, radium, whose radioactivity is very great. Among the particles expelled by radium are some which are ejected with great velocity, and their expulsion is accompanied with a considerable evolution of heat. A radioactive body constitutes then, a source of energy.

According to the theory which best accounts for the phenomena of radioactivity, a certain proportion of the atoms of a radioactive body is transformed in a given time, with the production of atoms of less atomic weight, and in some cases with the expulsion of electrons. This is a theory of the transmutation of elements, but differs from the dreams of the alchemists in that we declare ourselves, for the present at least, unable to induce or influence the transmutation. Certain facts go to show that radioactivity appertains in a slight degree to all kinds of matter. It may be, therefore, that matter is far from being as unchangeable or inert as it was formerly thought; and is, on the contrary, in continual transformation, although this transformation escapes our notice by its relative slowness.

In the beginning of the last century Coulomb and Ampère regarded each of the two kinds of electricity to be a fluid under the influence of central forces—repulsion existing between particles of the same fluid and attraction between particles of different fluids. Such forces would be proportional in the electric charge of the particles, and would vary in inverse ratio to the square of the distance between them. Starting with these hypotheses, and explaining suitably the observed facts relative to the different nature of conductors and dielectrics, they constructed a very perfect theory of

electrostatic phenomena. An analogous theory for magnetism may be built up by assuming that the law of action between two magnetic poles is absolutely like the law of action between electrified particles. The electric current was regarded as the flowing of an electric fluid in a conductor. To establish a theory of electro-magnetics and electro-dynamic phenomena, it is necessary to bring in a third law of action-at-a-distance between the magnetic poles and the electric-current law of Laplace. All these theories in their entirety are founded on the laws of forces acting at a distance, in combination with the conception of electric fluids.

Faraday, although contemporaneous with this development, looked at the question from a different point of view. He did not believe in the possibility or power of action-at-a-distance between electrified bodies, and thought that the forces which were exercised between them resulted from elastic tensions which established themselves in the intervening medium. These elastic forces comprise a tension in the direction of the lines of force and a pressure at right angles to them. In seeking to show the direct influence of the medium he was led to the discovery of the inductive power of dielectrics, and his belief in the essential part played by the intervening medium was thus strengthened. According to Faraday, the surface of charged conductors are to be regarded as surfaces of separation between regions where an electric field exists and fields of zero intensity.

He was struck by the barrenness of the efforts that had been made to realize an absolute charge, and electric charges always appeared to him as the ends of tubes of force which traverse the dielectric.

Maxwell, captivated by the ideas of Faraday, endeavored to explain them in mathematical language. He demonstrated that there does not exist in a mathematical view any incompatibility between theories based upon laws of action-at-a-distance and Faraday's theory of continuous action; and that by assigning a reasonable value to the tensions and pressures which Faraday conceived to exist in the dielectric, an electrostatic theory could be constructed identical to that which is derived from the law of action-at-a-distance. While Maxwell does not specify precisely the nature of electricity, he treats of it generally as a fluid whose displacement in a conductor gives rise to a resistance proportional to the velocity of the flow, while its displacement in a dielectric produces an elastic reaction. In a dielectric, displacement can only occur at the time when the field changes. One of the essential ideas of Maxwell was to consider the displacement of electricity in the dielectric as an electric current to which he gives the name of "currents of displacement." Currents of displacement, according to Maxwell, behave like ordinary currents, in the sense that they produce magnetic fields. Every open circuit in a conductor, following the opinion of Maxwell, is completed by a cur-

rent of displacement in the dielectric, so that there exist only closed circuits.

The system of the six differential equations, called Maxwell's equations, brings out in mathematical form the relation which exists at each point of an electro-magnetic field between the current of displacement and the magnetic field, as well as between the rate of change of the magnetic induction and the resulting electric field. These perfectly symmetrical relations show that all variations of an electric field cause a magnetic field, and vice versa. Starting from these equations, Maxwell proved that every perturbation of an electro-magnetic field should be propagated in a vacuum, with a velocity equal to that of light in a vacuum, and he draws the conclusion that the medium which transmits electro-magnetic actions in the vacuum is the same as that which transmits light, and that light is very likely an electro-magnetic phenomenon. This conception has served as the basis of the electro-magnetic theory of light, now universally adopted as the result of the experiments of Hertz and numerous physicists upon electro-magnetic waves. In the development of the ideas of Faraday and Maxwell, a preponderating influence was attributed to the rôle of the dielectric medium, so that little attention was paid for some time to the nature of electricity; and this question was relegated to a subordinate place, and received only an indirect interpretation. There was no longer the conception of charges of electricity localized in a determined region, nor of a fluid flowing through a conductor. The main conceptions were of energy localized in the dielectric medium and the differential equations which determine the field in the medium. Recent progress in research has brought us back to a more concrete conception of the nature of electricity.

The first impulse in this direction was the result of investigations of electrolysis and modern theories of this phenomenon. It was established with certainty that the passage of electricity in the electrolyte is always accompanied by the transportation of matter. Electrolytes are aqueous solutions of acids, bases, and mineral salts, or these bodies in a fused condition. It is now admitted that the molecules of a dissolved substance are totally or partially dissociated in two ions—one ion formed by the metal, or hydrogen, and charged positively; another formed by the acid radical, and charged negatively. When there is set up in the solution an electric field the ions move toward the electrodes of contrary sign, transporting across the liquid their charges, which they give up to the electrodes, and themselves become free in a neutral state. Ions are, then, the actual carriers of electricity in electrolytes, and the current is a current of convection. It follows from Faraday's laws that all monovalent ions carry the same amount of charge, q, corresponding to 96,600

coulombs per gram of ions, while an ion of valence, n, carries a charge nq. There can not be conceived in electrolysis an isolated charge of electricity less than that carried by a monovalent atom, such, for example, as hydrogen in the ionic state. The atomic structure of electricity is therefore an immediate and necessary consequence of the atomic structure of matter.

It is by no means evident, a priori, that this conception can be generalized and that the other known cases of conduction are susceptible of an analogous interpretation; but this seems to be coming to pass. The study of the electrical conductivity of gases has borrowed from the theory of electrolysis the idea of charged ions, vehicles of the current; and the phenomena are satisfactorily accounted for by the hypothesis that the current in a gas is a current of convection. But the vehicles of the current are not here the same as in an electrolyte. It is believed that an ionized gas gives rise to two ions, of which one is that minute thing which we call an electron, the other being the remainder of the molecule deprived of the electron. By ingenious methods the number of ions present in a given volume of gas has been counted and the charge carried by each one determined. This charge is equal to that transported by an atom of hydrogen in electrolysis, and thus we find this presented to us the second time as the smallest quantity of electricity which can be isolated.

All the phenomena of conduction across a gas under the influence of different forms of radiation or in the disruptive discharge at varying tension appear to be susceptible to explanation by the theory of the ionization of gases.

Attempts have been made to explain the conduction of metals in a similar way, and it is probable that this also may be considered as a current of convection whose vehicles are the electrons set free in the metal. Thus we arrive at the conclusion that electric currents through all forms of matter are currents of convection, or, in other words, the displacements of electric charges. Besides this it has been proved that any such displacement gives rise to a magnetic field.

The conception of the existence of atoms of electricity which is thus brought before us in the phenomena of conduction plays an essential part in modern theories of electricity like that of Lorentz. This theory retains the fundamental idea of Faraday and Maxwell, according to which the electromagnetic actions are always transmitted from place to place in a continuous medium with a finite velocity. This medium is the ether of space, and the velocity is the velocity of light. The laws of variation of an electromagnetic field in the ether are expressed at each point by the equations of Maxwell, and the causes which produce the electromagnetic field are sought in the existence of positive and negative atoms of electricity and in the motions of these atoms. We are thus returning to a conception which

recalls the old idea of two electrical fluids, only that we distinguish clearly the atomic structure of these fluids, and we understand better the relations which exist between the atoms of electricity and matter, a relation which is the most important aspect of the problem.

An atom of electricity in motion produces around itself an electromagnetic field which accompanies the movement of the particle, and which represents a certain quantity of energy whose amount is greater the higher the velocity of the charged projectile. It is not possible to increase this velocity without the expenditure of energy, and in consequence the charged projectile is endowed with a certain inertia. In mechanics inertia is used as a measure of the mass, and we may say that the atom of electricity possesses mass on account of its charge. Computation shows that the mass depends upon the velocity. It remains constant when the velocity of the projectile is small (about one one-hundredth the velocity of light), but for increasing velocities it augments very rapidly and tends toward an infinite value when the velocity approaches that of light, so that this is a limiting velocity which can not be realized.

It may be imagined that a group of atoms of electricity, both positive and negative, whose total charge is zero, possesses, nevertheless, inertia in consequence of the constituent electrical charges. This group might serve as a model of a material atom. Thus may be proposed a more general form of mechanics than that customarily considered, which is based on the constancy of mass. The latter would be no more than a first approximation to the truth, and holds good only for cases of motion where the velocity is not extremely great. Preliminary attempts have been made to explain universal gravitation between atoms constituted as above proposed. Altogether these studies tend toward an intimate fusion of the idea of electricity and the idea of matter, so that these two conceptions may yet be actually identified.

This proposed constitution of the atoms serves as an excellent foundation for a theory of the emission of light or radiation by a body. Such emission may be regarded as consisting of electro-magnetic waves of short period, emitted by an atom whose constituent ions are in a state of vibration. The same atomic structure serves also very well in the case of radioactive atoms. These atoms are in fact emitting corpuscles, some of which are electrons, others positively charged particles having a size comparable with that of atoms.

But we will not now penetrate further the domain of these theories, but turn rather to examine some of the phenomena which have served as a foundation for their development. It is well known that gases in their ordinary state, when exposed to a weak electrical field, have so insignificant a conductibility that they are regarded as remarkably good insulators. But it is not the same when the gases are under

the influence of certain exterior conditions, as, for example, the Roentgen rays, for in such conditions a gas becomes conducting. A charged electroscope in connection with a metallic plate in ordinary circumstances loses its charge but slowly. If, however, a stream of Roentgen rays penetrates the air around the plate, the discharge proceeds rapidly. It is not necessary for the Roentgen rays actually to strike the plate, but suffices that the air be traversed within a distance where the electric field is still sensible. This is shown by constraining the Roentgen rays to follow a tube impenetrable to them, and thus shielding the plate from their path, so that it is certainly the gas which is modified and rendered conducting. We say that the gas is ionized, some of its molecules having been decomposed by the rays, and that each of these has given rise to the formation of two ions laden with equal electric charges having opposite signs. The ions are put in motion under the influence of the electric field with a velocity which increases with the strength of the field. If the electroscope is charged positively, the negative ions are drawn toward and discharge it, while the positive ions go in the opposite direction and neutralize the charge found at the extremities of the lines of force which emanate from the plate.

If the gas which has been under the influence of the rays is left to itself without the action of any electric field to move the ions, its conductivity disappears spontaneously, and we say that the ions have recombined to form neutral molecules.

There appear to be in the gas movable charged centers, which travel toward the plate of the electroscope. These centers may be intercepted by means of a screen of paraffin. The screen should not itself be charged, as may be tested by means of a second electroscope. The positively charged plate of the first electroscope may now be covered with the screen, and the Roentgen rays then allowed to act for a time. Negative ions moving toward the charged plate are arrested by the paraffin, and they charge the screen negatively. This may be verified by again bringing the paraffin screen near the second electroscope.

It may be shown that under the action of the Roentgen rays the number of ions produced in a gas in a given time is definitely limited.

The rate of discharge of the electroscope is measured by the rate of fall of the gold leaves; and it increases with the electric intensity of the charge, as may be easily understood. Therefore, the stronger the electric field and the greater the velocity the less is the chance that the opposite ions draw together. But for a charge sufficiently great, the rate of the discharge no longer depends on the amount of the charge and does not increase as it augments. Under these circumstances there are no longer any recombinations of ions; they are all utilized for conducting the current, which can not exceed what they can carry.

Such a current is called a current of saturation. It is constant for a given intensity of radiation independent of the sign of the electric charge.

An important difference shows itself between the properties of positive and negative ions. This difference is easily shown by the gases of flames. These gases are ions and conductors, and the approach of flame promotes the electric discharge. Contact with the flame is not necessary. It is sufficient that the ions are produced within the region covered by the electric field. The attraction of the charge of the electroscope suffices to draw from the flame the ions of contrary sign, which neutralize it, and this phenomenon takes place, whatever the sign of the charge. But an isolated flame placed between the two plates of a charged condenser inclines toward the negative field; hence we conclude that the flame is then charged positively. This is because the negative ions produced in the flame are smaller and by far more active than the positive ions, so that they are more easily drawn from the flame, and thus there is left with it an excess of positive electricity. In a cold gas the positive and negative ions have a nearly equal mobility, which is less than that found in a warm gas. They are thought to be in this case formed by the agglomeration of molecules grouped by electrostatic attraction about the charged centers. The dissimilarity between positive and negative ions manifests itself in certain cases even in their formation. This is shown, for example, in what is called the phenomenon of Hertz: Certain negatively charged metals, such as zinc, lose their charge when illuminated by ultraviolet light, but if the charge is positive the illumination produces no discharge. It seems to be proved now that zinc and some other easily oxidizable metals has the property of spontaneously giving off electrons under the action of ultraviolet rays. If the emission is given off in a vacuum the electrons are able to acquire a very high velocity in an electric field, and they comport themselves then like the cathode rays of Crookes tubes. If the emission takes place in the air at ordinary pressure the electrons surround themselves with agglomerations of neutral molecules, and form ions of little activity, like those ions which are formed in the air by the Roentgen rays. But in either case the discharge is nonreversible and takes place only if the metal is negatively charged, for the metal is not able to emit negative electrons if the departure of them is obstructed by the attraction of a positive charge residing upon the metal.

Thus we see why it is that gases may become conductors under the influence of certain radiations, or of the combustion of flames. It has been known for a long time, however, that without any of these influences a gas can not prevent the passage of electricity when the field is sufficiently strong. The phenomena of the disruptive discharge, including the spark, the arc, and the brush discharges, have

long been known, and they take various and complicated forms in the air at different pressures; but until recently they have been very little understood. The theory of gaseous ions has thrown a new light upon this manner of discharge. As a result of recent researches, the disruptive discharges can be explained by assuming that the ions which have acquired a sufficient velocity under the action of an electric field are able to act as projectiles, which, coming in contact with the molecules of gas, ionize them by the shock which they produce. Negative ions are much more active ionizing agents than the positive ions, and can produce these effects in more feeble fields. It may be conceived, then, that the ions being multiplied by the shock of those already present, the conductibility of the gas becomes very great when the field is sufficiently strong, and the ionized gas is then luminous.

The cathode rays, which are produced when the discharge is made to pass in a tube containing a gas under low pressure, are the electrons sent off by the cathode with a great velocity. Since these electrons and the positive ions have different properties, the discharge tube takes on the well-known dys-symmetrical appearance, which the theory of the ions readily explains, but for which no other interpretation has sufficed.

The Roentgen rays, which are emitted from a Crookes tube, are believed to be in reality electromagnetic waves whose wave length is very short. Such waves as these are supposed to be emitted by an electron whenever it is subjected to an abrupt acceleration, such as is produced, for example, when the electrons of a metal are put in vibration by the impact of cathode rays.

In accordance with what has been said, all gases which show themselves conducting contain the charged centers which we call gaseous ions. The presence of these charged centers may be made evident by means of a very curious experiment, which utilizes the property which ions have of promoting the condensation of supersaturated water vapor. When the volume of a certain mass of saturated water vapor is quickly increased the vapor condenses to the extent to which it is supersaturated, but if the supersaturation is not very great, and if the vessel contains no dust, there is no noticeable condensation at the moment of change, and the gas remains transparent; but when the gas contains ions the condensation takes place readily—that is to say, with a smaller expansion. It is easy to regulate the expansion so that there will be no condensation when the gas is not ionized but an abundant condensation if ionized. In the latter case the condensation manifests itself by the formation of an opaque cloud which fills the receptacle. Investigation of this phenomenon has shown that the globules of water, which constitute the cloud, form themselves upon the ions, each of which serves as a center for one of them.

Ingenious experiments have made it possible to count the globules present in a cubic centimeter of cloud and thus to obtain the number of ions present in this volume. By measuring, in addition, the total charge of the ions of each sign in a cubic centimeter the individual charge of the ions is determined—that is to say, the charge of a single atom of electricity. This charge is equal to 3.4 times 10^{-10} electrostatic units. In order to show this phenomenon the gas may be ionized by the introduction of a glowing platinum wire, and it will be recognized that there is an energetic ionization of the gas surrounding the incandescent body.

We will now pass to the essential facts revealed by the study of radio-active substances, and examine them from the point of view of the hypothesis of the atomic transformation of matter. Among the radioactive elements, some appear to be permanently active (uranium, thorium, radium, actinium) while others lose their radioactivity little by little (polonium). The most powerful representative of the permanently radioactive substances is radium. According to the theory of transformation this substance changes very slowly, so that a given mass of radium would lose half its weight only in several thousand years. Consequently the quantity of radium which disappears from a gram of this substance in an hour is absolutely inaccessible to experiments. However, a gram of radium disengages each hour about 100 calories of heat. To conceive how enormous this disengagement of heat is, we remark that during the life attributable to radium the complete transformation of a gram of this substance would produce as much heat as the combustion of a ton of coal. The transformation of radium, then, if transformation there be, is not to be regarded as an ordinary chemical reaction, for the quantity of heat involved is of a far higher order. One is led to conceive, rather, that the atoms themselves are transformed, for the quantities of energy put in play in the formation of atoms are probably considerable.

Indeed, the phenomena of radioactivity has a palpably atomic character which was brought to light in the beginning of researches on the subject. It was precisely the absolute conviction that we were dealing with an atomic phenomenon which led M. Curie and me to the discovery of radium. If the radioactivity can not be separated from the atom it is very difficult to conceive anything but the atom itself involved in the transformation.

The effects produced by radium are very powerful considering how small is the quantity of this substance at disposal for experiments. There is a spontaneous and continuous emission of rays, analogous to those which we know are produced by means of an induction coil in a Crookes tube, and these rays produce ionization of gas in the same manner. They are able, for example, to produce

the rapid discharge of an electroscope. The energy of the rays is so great that the discharge is produced even across a thick metallic screen, for the rays can traverse such a screen.

Some of the rays comprise electrified particles moving with very great velocity. Some are charged positively, and their dimensions are comparable with those of atoms; while others are negative electrons, whose electric charge may be shown by direct experiments. Admitting that all these projectiles come from the atoms of radium themselves, it is difficult to avoid the conclusion that the departure of a positive particle must necessarily cause a modification of the atom which expels it.

Among the electrons emitted there are some whose velocity is enormous, and is in fact no less than nine-tenths the velocity of light. It has been found that the mass of these projectiles (which are the most rapid that we know of) is greater than that of slower-moving electrons, and this result may be considered as a confirmation of the theory according to which the mass of an electron is regarded as the result of electro-magnetic phenomena.

The energy of the rays of radium is also manifested by their capacity for exciting the luminosity of various phosphorescent substances. Radium salts are, indeed, themselves luminous, and the light is readily visible in certain conditions.

Here are now a new series of facts which are interpreted by the theory of radio-active transformation. Radium disengages continuously a substance which behaves like a gaseous radio-active material, and which has received the name of *the emanation*. Air which has been in contact with a solution of radium salts is charged with the emanation, and may be drawn away and studied. Air containing the emanation is strongly conducting. A sealed glass tube in which the emanation has been imprisoned acts on the outside like a radioactive substance, and is able, for example, to discharge an electroscope. When the emanation is drawn into a flask containing zinc sulphide, the latter becomes luminous. The emanation is an unstable gas and spontaneously disappears, even from a sealed glass tube, at a rate in accord with a strict law, by which a given quantity of emanation diminishes by half in about four days. The emanation possesses the property of imparting radioactivity to all the bodies in contact with it, and such bodies are said to possess induced radio-activity. Here is a tube of glass which did contain emanation, but contains it no longer, for it has been purged by a current of air; nevertheless this tube continues to act as a radioactive body, and is able to discharge an electroscope. But this induced radioactivity is even less durable than the emanation; it disappears spontaneously and diminishes by half in a half hour.

In the theory of atomic transformation the emanation of radium is the first product of disintegration and is transformed in its turn. The induced radioactivity to which it gives rise is considered as due to a solid radioactive material, which results from the transformation of the radium emanation. Three different radioactive materials are distinguished in the induced radioactivity, which constitute three successive terms of the transformation. Each transformation is also accompanied by the emission of rays, and the expelled particles are also counted among the resulting products.

Induced radioactivity does not disappear completely; but there remains after the lapse of a day a very feeble residue which persists in part for years, and which is believed to be adding new terms to the series of successive transformations.

A new fact of great interest has come to the support of the theory of the transmutation of radioactive substances, and has, indeed, made it almost indispensable. It has been proved that radium, a perfectly definite chemical element, produces continually another perfectly definite chemical element, helium (Ramsay and Soddy). It is admitted that helium is one of the products of the disintegration of the atom of radium, and it is noteworthy that helium occurs in all the radium-bearing minerals.

The theory of the radioactive transformation has been extended to all the radioactive bodies, and investigations have been made to determine if the radioactive substances heretofore considered as elements are not to be derived from one another. The origin of radium itself has been sought in uranium. It is well known that radium is found in the uranium-bearing minerals, and it appears from recent researches that the proportion between the quantities of radium and uranium is the same in all these minerals. Uranium may, then, be thought of as a mother substance, which disintegrates with extreme slowness, giving place to the production of radium and the products which succeed it. It appears also to be probable that the last term of the radioactive series is polonium. It may be recalled that uranium was the substance in which the property of radioactivity was discovered by M. Becquerel, and polonium is the first new substance which was discovered by the aid of the phenomenon of radioactivity.

A series of analogous considerations has been established for another radioactive substance—thorium. In this case thorium as a primary substance generates radio-thorium, a substance recently discovered, which gives rise to the gaseous radioactive emanation of thorium and various products of radioactivity induced by this emanation. Actinium also gives place to a series of transformations similar to those of thorium, and it, like radium, produces helium.

All the radioactive substances which have been studied sufficiently from the point of view of their disintegration follow a law of decreas-

ing progression, characterized by a constant coefficient. This coefficient may be defined as the time required for the diminution of the activity by half. These constants appear to be independent of the conditions of experiment, are characteristic of the substance to which they appertain, and seem to be capable of fixing an absolute scale of time. Thus the emanation of radium diminishes by half in about four days, while that of thorium diminishes by half in about one minute, and that of actinium in about four seconds.

I have already stated that the radioactivity is a general property of matter. If the theory of radioactive transformation continues to inspire a growing degree of confidence, it will result in an important consequence for geology, and will lead to a careful study of the proportions of the elements occurring in rocks, with a view to deduce their relative ages.

It is plain that the hypothesis of radioactive transformation is well adapted to the present state of the science of radioactivity. It was among those proposed by M. Curie and myself at the beginning of our researches on radioactivity;[a] but it has received its precise development by Rutherford and Soddy, to whom it is for this reason generally attributed. It seems to me, however, better not to leave the domain of demonstrated facts, and not to lose sight of other explanations of radioactivity which have been proposed. The actual state of the science does not seem to me far enough advanced to warrant a positive conclusion.

In closing, the general importance of the phenomena of radioactivity may be recalled. For physics the radioactive substances constitute a new implement of research in consequence of the rays they emit, and they have actively contributed to the development of the theory of the conduction of gas and of the nature of the electron. By their numerous chemical and physiological effects, and their possible influence on meteorology, these substances extend their sphere of action in the domain of all the science of nature; and it is probable that their importance for the development of science will go on increasing. Finally, it has been shown that there is nothing absurd in supposing that the energy we receive from the sun may be in part, or even in total, due to the presence of radioactive bodies which it may contain.

[a] Mme. Curie, Revue generale des Sciences, January 1899, and Revue Scientifique, July 1900.

RADIOACTIVITY.[a]

By Prof. Dr. Franz Himstedt,
Prorector of the University of Freiburg in Breisgau, Baden, Germany.

In December, 1895, Röntgen made his first communication regarding the X-rays to the physical medical society in Würzburg, and early in 1896 Becquerel submitted to the Academy in Paris a treatise in which it was authoritatively announced that he also had discovered a species of rays not less wonderful, namely, those emitted by the radioactive substances.

A decade only has passed since then, but a decade so fruitful in the discovery of new facts, so radically revolutionizing opinions and views maintained for a century and apparently unassailable, and so suddenly lighting up for us regions hitherto shrouded in deepest obscurity, that another like it can hardly be pointed out in the history of physics. And since it is incumbent on me to-day, after the old academic custom, to enter upon the office of prorector with a short address relating to my special department of research, I feel that I can choose no more fitting theme than radioactivity. I believe that not only the recent phenomena in this field, but also the attempts at their explanation and a statement of the new views which now obtain regarding the constitution of matter, will prove such as to arouse interest far beyond the circle of those concerned mainly with physical science.

In his first treatise on the X-rays, Röntgen drew attention to the fact that they proceeded from those parts of the Röntgen tubes where the glass, under the influence of the impinging cathode rays, showed the most fluorescence. It therefore seemed possible that the existence of these mysterious rays was in some way dependent on previously acquired fluorescence, and many physicists tried to ascer-

[a] Translated, by permission, from Reden, gehalten in der Kunst-und Festhalle am 16 Mai 1906 bei der öffentlichen Feier der Übergabe des Prorektorats der Universität Freiburg i. Br. von dem abtretenden Prorektor Prof. Dr. Theodor Axenfeld und dem antretenden Prorektor Geh. Hofrat Prof. Dr. Franz Himstedt, Freiburg i. Br. Universitäts-Buchdruckerei U. Hochreuther, 1906, pp. 31–63.

tain with the well-known Balmain dyes, which become luminous after exposure to the light, if results could be obtained resembling those with a Röntgen tube.

Similar attempts by the French physicist, Henri Becquerel, were crowned with success in an unexpected direction. He exposed a uranium salt to the light, and then placing it in a dark room on a photographic plate covered with opaque paper he demonstrated the action of these rays on the plate through the paper, thin sheets of metal, etc. But the supposed and sought-for relation of the rays to the previous fluorescence was not evident, for Becquerel obtained precisely the same results with preparations of uranium which had not only not been previously exposed directly to the light but had purposely been kept sometime in darkness and could therefore display no stored-up luminescence. He had, however, discovered the uranium or Becquerel rays. Prof. C. C. Schmidt, in Erlangen, afterwards obtained similar results by experiments with thorium and its compounds, and thus became the discoverer of the thorium rays.

At Becquerel's suggestion Madame Curie undertook a systematic investigation of all the chemical elements and established the fact that with none of them, excepting uranium and thorium, could an appreciable effect indicating rays be obtained with her apparatus. On the other hand, she found that many of the minerals investigated showed noticeable action in this direction. The fact that a few of them, the uranium pitchblende, for example, from Joachimsthal, Bohemia, emitted rays three or four times stronger than those of pure uranium, and which could not therefore be announced as uranium rays, led her to suppose that in the pitchblende itself, apart from the uranium, there must exist a still more powerful radioactive substance. It is a matter of record how, in this research, which might serve as a model for such work, she and her husband, so soon afterwards to lose his life by a deplorable accident, succeeded in tracing this supposed substance more and more accurately, and finally in obtaining it pure. Madame Curie thus became the discoverer of radium, a new element possessed of wonderful, of fabulous qualities.

Besides Madame Curie no other investigator but Professor Braunschweig, so far as I know, has yet succeeded in obtaining pure radium. The difficulty of conducting this research will be appreciated when I refer to the fact that out of a carload of pitchblende from Joachimsthal, the most rich in radium of any material so far known, Madame Curie secured in all but one-fourth of a gram of radium chloride. Out of a mass of 1,000 kilograms to secure its four-millionth part, in a substance evenly diffused through it, is a record of chemical analysis which surpasses a hundredfold all previous work of the kind, and success in this attempt became possible

only because the substance sought for possessed the exceptional quality of radioactivity.

A radium crystal emits three different types of radiation, which, as suggested by Rutherford, one of the most successful investigators in the domain of radioactivity, have been designated as α, β, and γ rays. The existence of these rays can not be directly perceived by any of the senses; we are only indirectly made aware of their presence by the phosphorescence which they excite, by their action on a photographic plate, and by the electrical conductivity which they arouse in the atmosphere and in the gases.

When we see a radium crystal shining like a glowworm in a darkened room, it is because the crystal itself has been excited to fluorescence by the rays, exactly as a Röntgen screen or the Sidot-blende can be made fluorescent by the same means. The sensation of light experienced when the crystal is laid on the temple or on the closed eye is due to the fact that every part of the eye itself, and especially the lens, becomes luminescent under the influence of the radium rays.

The most important property discovered in the investigation of radioactivity is the power of the rays to render the atmosphere and the gases, which are generally good insulators, electrically conductive. If we charge an insulated body like the ball of a gold leaf electroscope with electricity it will be an hour or more before we can detect any diminution of the charge by the slightest divergence of the gold leaf; but if we bring a radium preparation into the vicinity of the instrument the leaves suddenly collapse and the electrical charge disappears almost instantly. If instead of the electroscope we take one of our highly sensitive electrometers, we have a mode of experiment a thousand times more sensitive to the slightest traces of radioactivity than any other known method of physical and chemical analysis. This apparatus, with the helpful aid of photography, has been of vast use in determining the direction of the α, β, and γ rays, and have thus added materially to our knowledge of the subject.

The α rays act like positively charged bodies of the size of the chemical atom which are projected from radium with the greatest velocity. They are so slightly penetrating that a sheet of paper is impervious to them, and they are absorbed by a layer of air a few centimeters thick.

The β rays are negatively charged bodies, which in every regard resemble the cathode rays produced in a vacuum tube when an electric charge is sent through it. These rays have become widely known from the fact that the Röntgen rays originate at the point where the cathode rays meet with an obstacle.

The γ rays are analogous to the most penetrating X-rays, and act on a photographic plate and Röntgen screen through a sheet of lead 10 cm. thick. Many observations indicate that the γ rays originate through the β rays in the same way as the Röntgen through the cathode rays.

In radium we have not only an everlasting lamp, a fountain of light shining day and night, but in this mysterious substance we have also a stove which constantly radiates warmth without having been itself heated. A gram of radium produces 100 gram-calories every hour. A kilogram of radium would warm a room, and if we should weigh our supply of fuel at the end of the winter we should find it to be still a kilogram and still giving out the same amount of warmth. An admirable way of heating, one would think, but not cheap after all, for a kilogram of radium, if it could be procured, would cost 100,000,000 marks, about $25,000,000. Even if one had the money, such a mode of heating could not be adopted on account of the noxious effect of such a quantity of radium, which if left uncovered in a room would destroy all life there within twenty-four hours. In spite of every precaution, investigators who have worked with radium have suffered from abscesses and the like, which prove remarkably difficult to heal. If the finger is held for a few minutes over 20 to 30 mg. of radium the skin is inflamed and peels off in from eight to fourteen days. These experiences have given rise to the idea that the radium rays might be used in the treatment of malignant tumors—that is, lupus and carcinoma—but it is as yet impossible to say whether or not these awful scourges of humanity may be successfully treated in this way.

It is not, however, improbable that the healing power of radium has contributed for centuries to the aid of mankind, as research has proved that all natural springs contain radium emanations, and that the quantity is greatest in the well-known healing, thermal springs. This may be a mere coincidence, but the established fact that the healing power is greater in the waters which possess the greatest amount of radioactivity, favors the theory of cause and effect, as does the fact that these waters when carried to a distance lose something of their curative power and their radioactivity at the same time. Swamp and fango earth possess a not inconsiderable quantity of radium, which apparently indicates that the curative power of baths of this sort is in proportion to their radioactivity.

Since all springs possess radioactivity and traces of the same property are found in subterranean streams, we must draw the astonishing conclusion that this remarkable element is widely distributed throughout the interior of the earth, an element of whose existence no one had a suspicion a decade ago, and of which up to this time we have been able to isolate only the most infinitesimal quantities, hardly more

than a gram in all. When we consider also that radium constantly produces heat, the question is forced upon us whether this store of heat has not already played an important part in the constitution of the earth, and whether it may not now do so. Indeed, we may ask the still more astonishing question, whether heat production by the means of radium may not be considered in connection with the heat of the sun on which all life on our globe depends.

If we combine the Kant-Laplace hypothesis of the origin of our sun system with the principle of energy, we reach the conclusion, as Helmholtz has shown, that the existing supply of heat in the sun may have arisen from the process of contraction, through which it was formed in the beginning out of chaotic masses of nebulae, and that the continued radiation of heat by the sun is caused by the now slower but still progressive contraction of the sun's mass. It is evident that if the existent amount of radium produces such enormous quantities of heat, we must suppose the process of contraction to have proceeded correspondingly slower, and we may therefore assume a much longer existence than heretofore supposed, in the past as well as in the future, for both the sun and the earth, a conclusion which agrees with the vast periods of geologic development established by quite different facts and researches. Still this and similar questions to which the discovery of radioactivity has given rise must remain in abeyance so long as the chief problem, whence does radium derive its emitted energy, remains unsolved. We have asserted that a crystal of it constantly emits α, β, and γ rays, can diffuse noticeable quantities of heat and, tested by the most exact measuring instruments, still remain the same. How can this be reconciled with the law of the conservation of energy, which we know all the processes of nature obey? "The universe," says Helmholtz, "has its limited supply of energy, which works in it under ever-varying forms, indestructible, incapable of increase, eternal, and unchangeable like matter." We define physics as the science which treats of the transformation of energy while conserving the quantity. We distinguish between mechanical, chemical, and electrical energy, the energy of sound, of light, of heat, and we assert that all physical processes in nature consist only in the change of one kind of energy into the equivalent quantity of another. No energy can be lost, and none can be created. When we see, therefore, that radium is continually giving out energy, and this fact is absolutely proved by manifold experiments, we are compelled to ask, Whence comes this energy and from what is it derived?

None of the processes of nature hitherto known to us can give the answer, and we are confronted by a perplexing alternative: The principle of energy, which we have hitherto held to be the highest guiding law of the natural sciences, is false, or there are natural

processes we so far have had no conception of and in which a million times greater amount of energy is set free than any we have as yet been in a position to investigate.

Some time ago a happy combination of circumstances relieved us of this painful uncertainty. Observations in various fields—in optics, electricity, and radioactivity—have worked together to point out what these processes might be, and we have been fortunate enough to observe directly such an illustration.

All the processes hitherto known to us may be described as molecular; our chemistry is a chemistry of the molecule. We have investigated how the molecule may be built up out of the atom of the chemical elements or may be disintegrated into atoms again, and we have learned to measure the energy thus transformed. The chemical elements and their atoms have hitherto been for us the completed, the fixed, building stones which all science has tried in vain to transform. But now we believe that we have advanced a step farther, and are able to show that the elements are not unchangeable, the atoms not indivisible.

It was unquestionably one of the greatest strides forward in the domain of physics and chemistry when the fruitless speculations and senseless experiments of the alchemist were brought to an end by the ever-strengthening theory that the universe was built up of atoms, of a limited number of simple, unchangeable, chemical elements. The brilliant developments and great achievements of chemistry were not less adapted to support this theory than the previous but always fruitless attempts to disintegrate the chemical elements, to divide the atom.

On the other hand, one may not now assert that the separate elements stand unrelated to each other, but must rather acknowledge their interdependence. The most striking demonstration of this is the periodic system of the elements formulated by Lothar Meyer and Mindeljeff, which clearly shows that the properties of the elements are periodic functions of their atomic weight. When observing, for example, the group Li, Na, K, Rb, Cs, elements of remarkably similar characteristics, is it not surprising that I have the atomic weight of each succeeding one in the column if I add 1×16 or 3×16 to the preceding? That this is the confirmation of a law and not a chance play with figures is proved by the fact that Mindeljeff, because of the gaps in his tables, prophesied that such and such elements, with certain characteristics, would be found, and they were found—gallium, scandium, germanium—exactly as he had foretold. What is the significance, then, of the 1×16 and the 3×16 in the above example? Would that I could solve that, but it is beyond my power.

Every chemical element gives out, like a glowing vapor, a spectrum in which the colors are not continuous and merged into each other

as in the rainbow, but which in the spectral apparatus are shown as a smaller or larger number of luminous lines characteristic of the element in question, and separated by dark spaces between. These lines have been divided into series, which show us that the light emitted by an atom consists of a number of separate vibrations, which may not, after the analogy of acoustic phenomena, be regarded as the fundamental tone and the overtone of a vibrating body, but show that the atom must consist of a larger number of minute bodies, themselves vibratory.

In the sun, where the temperature is about twice as high as the most intense heat in our power to produce, the number of elements is smaller than on the earth. In the stars, whose temperature, like that of Sirius, for example, is higher than that of the sun, the number of the elements is still smaller. Is it not reasonable, then, to suppose that the number of elements in a heavenly body depends on its temperature and that through heat the complex elements are subdivided into simpler ones? Yes; and if I could only accomplish that through experiment, but it is again beyond my power. All these and many similar phenomena indicate a possible disintegration of the elements, but they do not avail to produce the experimental proof. However, such a thing has now become possible. "Bodies which are smaller than the atom" have been found by an exhaustive investigation of the cathode rays, to which the most distinguished physicists of every country have devoted their science and skill, J. J. Thomson, of Cambridge, standing in the first rank among them.

We speak of the cathode rays, now so often mentioned, as of a stream, like water, for, as before stated, they consist of a current of the most minute particles, carrying a charge of negative electricity and moving with the greatest swiftness. But how explain the fact that these rays, these particles, can go through solid bodies without harming them? Such a thing would be impossible unless the particles are so minute that substances as impenetrable as wood, or metal even, would be to them like a coarse sieve.

At the first glance it seems against nature that anything should pass through iron and steel plates, until we remember that it is only a question of relative size. The elephant needs a door at least 2 meters high and 2 wide, and then perhaps goes through this great opening less easily than most bacteria through the million times smaller meshes of the finest hair sieve. Why not, then, picture to ourselves forms which are a million times smaller than the smallest bacteria? It is only the question whether or not we can prove that such really exist. We have thus, you see, to demonstrate the dimensions of a cathode ray particle. Direct measurement in this case is still less possible than the measurement of an atom. However, through the ingenious combination of the results of several

researches, we are able to compare mathematically the size of such particles with the size of an atom.

I have already referred to the fact that the cathode rays carry a negative electric charge, and it has been demonstrated that each particle contains a so-called elementary quantity of electricity, or the amount that an atom of hydrogen carries through the galvanic stream at the decomposition of water. We should therefore think it reasonable if such a particle were of the same size as the hydrogen atom. On the contrary, the astonishing fact appears that the size of a cathode-ray particle is at least one thousand times less than that of the hydrogen atom, the smallest of all hitherto known atoms; that is, a thousand times smaller than the body, which, as the name implies, is so minute as to have been heretofore considered indivisible. This recently discovered particle carrying an elementary quantity of negative electricity has been named an electron.

It will be readily believed that physicists would not accept a statement so contradictory to the views previously held without rigid examination, and that the existence of the electron would not be credited without further proof. But since numerous investigators, working by different methods, have found the same value for the mass of the unknown electron, and after this value has proved itself invariable, whether the electrons were produced by an electric discharge through a vacuum tube, or by an illumination with ultra-violet or X-rays, or by means of a Bunsen burner or a thorium preparation, and, further, after it has been shown that it is entirely indifferent which gas we work in, whether hydrogen, oxygen, or the air, we can not deny the fact that a negative electron of a mass approximately one one-thousandth of that of the hydrogen atom can be isolated from every substance.

The question at once arises, have we here the primal substance informing all matter and out of which the entire universe is built up? Is the electron the already long sought for primary atom, through the grouping of which in varying numbers and diverse positions all material substances, and consequently the primary elements themselves, originate? May we not hope that the chemical structure of the atom depends on the chemical structure of the molecule? Since each chemical atom is characterized by its own spectrum, may not one imagine that each atom illustrates in an infinitesimal degree a planetary system, in which the central body would be a positively electrified germ around which, according to the element under observation, a differing number of electrons perform their revolutions in prescribed paths, exactly as the earth, Mercury, Jupiter, Saturn, and the rest continue their endless circuits around the sun? Many physicists believe this to be so, but it is still too early, would lead too far, and as yet we know too little about the electron to attempt to decide

this question. We are satisfied to have established the fact that there are atomic processes, that an atom is not indivisible, and that smaller particles may be isolated from it.

We were attempting to find an explanation of the enormous quantity of energy given out by radium, but has the knowledge of the composite nature of the atom brought us farther in this direction? Yes, undoubtedly, for there are many reasons to believe that if a body so apparently indivisible as the atom, one which so long resisted all our efforts, may be subdivided, that there must be enormous stores of energy which can be set free, differing entirely from those we have had an opportunity to study in the molecular processes and by the ordinary chemical methods. The question then follows: Is there ground for the belief that a similar atomic disintegration may take place in radium? Undoubtedly so, for the present condition favors the belief that radium is constantly sending out cathode rays and generating electrons. We are furthermore able to produce a more direct proof which may be postulated directly from the electron theory, and which admits of demonstration quite independent of that hypothesis.

When an atom gives off an elemental electron its weight must thus be lessened, which is in effect to say that the atom is no longer a component part of the former element but has united with another. We assert, therefore, emphatically that since proof has been given that atomic processes are possible, that atoms separate and can subdivide themselves, it must be possible that one element may convert itself into another, or, for example, that gold may come from lead. Whether we shall ever succeed in converting gold into lead is quite another question, which I will not discuss now, but the investigation of the electron favors the belief that such a transformation is not impossible. And in radium it has in fact been made possible to observe the process of the change of one element into another. Rutherford foretold it, and Ramsay and Soddy were the first to bring proof of the transmutation of the radium emanation into helium.

If a radium preparation is placed in a glass container in a darkened room, a weird, grayish, but slightly luminous, sort of a mist is seen to arise from it. If the container is closed, it is gradually filled by this mist, or gas, which steadily gains so much in luminosity that in a day or two one can tell the time on a watch by it. If this luminous fog is blown out of the glass, the play begins over again until the container emits light as before. The so-called radium emanation is thus seen to develop itself continuously.

What is it? I conduct the luminous air which contains the emanation through the strongest gases and lyes and it remains unchanged. I conduct it over incandescent copper or magnesium and it is the same. I have no power over it. I transmit it through a tube which

has been cooled in liquid air and the emanation is no longer luminous, but the walls of the cold tube emit strong light. I consequently decide that the emanation is a gaseous body which, as more exact research has proved, condenses at 150°. It emits α rays, which the air renders luminous and electrically conductive. Without these properties in the emitted rays we should never have discovered the gas, for our supply of radium is almost invisibly small. Ramsay and Soddy announce that from 60 mg. of radium they obtained in four days one-fiftieth of a mm.^{3} of the pure emanation, unmixed with air; that is, an amount which would fill a receptacle scarcely so large as the head of a small pin. Imagine this amount to be diffused through the laboratory of a physicist, and he would hardly be aware of it, but perhaps not because it was so little, but because it was so much that his apparatus would refuse to work, its isolation being destroyed. This illustration gives an idea of the sensitiveness of the methods through which we can discover the minutest traces of the radioactive substances by estimating the conductivity of the atmosphere.

If we succeed in collecting a like amount of the emanation in a glass vacuum tube, it will emit a bright light, which in a few days will become noticeably weaker, and in a few weeks will disappear, while we find in its place, by exact spectroscopic experiment, traces of a gas which certainly was not present before, namely, helium. These experiments have been conducted in the most diverse circumstances by many investigators, a part of whom approached the task with no expectation of finding this result confirmed, so that there is no room for doubt that radium, a chemical element, as positively defined as gold or iron, or as any emanation which has been secured, transforms itself into helium, an equally sharply defined element.

We have thus seen one element transformed into another, an occurrence never before witnessed and long held impossible. In such a process, which is possible only by a change in the atom itself by the separation of a part of it, an enormous amount of energy must be set free, and when such a process actually takes place in radium an appreciable amount of warmth must be obtained; but in spite of this we can discover no change in the weight of the preparation itself. One difficulty in bringing the phenomena of radium into accord with the principle of energy is now removed. Instead of a failure of the principles of the natural sciences, held unchangeable by the timid doubter of the phenomena of the radioactive substances, the view of an entirely new world, the world of atoms, has been revealed to us. We need no longer stop with the chemical elements, but may study the origin and dissolution of these forms also, which have hitherto been held as preexistent and unchangeable.

In fact, gratifying advance has already been made, especially by

the experiments of Rutherford, in this direction. Consequently we have uranium, the element with the highest atomic weight, consisting of the greatest number of electrons and which, in accordance with the electron hypothesis, we accept as the mother substance. A something which so far we have been unable to seize hold of and to analyze isolates itself from the mother substance and we have radium, out of which, as already noted, the radium emanation arises. We know the constituents into which this separates—namely, helium and the so-called "radium A." Then radium B appears and out of it radium C, and so on until we reach radium G. These intermediate products, called "metabolons," are so far known to us only through their radioactive properties. No one has yet seen, weighed, or measured them; but in spite of this we are able to distinguish them by the rays which they emit, as well as by their period of duration.

Let us take, for example, the radium emanation B, whose presence we note through the luminosity of the air, and it is easy to show that this emits only the slightly persistent rays which, deflected by a magnet, show the characteristics of a positive electric charge. If we leave a body for a day or two in this emanation, it begins to show itself radioactive. It might be said that this is only from the traces of the emanation left on its surface, just as a platinum wire would show traces of hydrogen gas in which it had been left. It is true that something which I can not see with the finest optical instruments, but which I can remove with muriatic acid, or by polishing with sandpaper, has attached itself to the surface of the body. This product is certainly not an emanation whose rays, as well known, will not go through a sheet of paper, while with the rays emitted by the piece of wood, glass, or metal, which I have left in the emanation I can influence a photographic plate through a screen. The rays emitted by the body thus treated, whatever it may be, whether a needle, pencil, cork, or morsel of bread, are hardly less penetrating than the Röntgen ray. And not only by the nature of the ray, but by its duration can it be shown that it is now a question of a new substance. The measure of the duration of activity, or the half-value, as that time is called during which the activity of these substances is diminished one half, has been one of the most serviceable means of identifying them. A radioactive body is one in process of transmutation, and experience has shown that this action always proceeds at the same rate in a given substance. The radium emanation loses one-half of its activity in four days; radium C, the more penetrating rays of which I have just referred to, does the same in twenty-eight minutes. The half-value of the thorium emanation is fifty-four seconds; on the other hand, the half-value of the excited thorium activity corresponding to radium C, is eleven hours. Given an unknown radioactive substance to identify, I estimate the

activity of a certain ray which it emits, repeating the experiment in from one to two hours. I then estimate the decay of activity during this time and thus decide whether I am dealing with a new or a known substance. We are thus in a position, as has been said, to distinguish disintegration products of uranium down to radium G, and to determine their characteristic radiations and half-value times.

It may be said that in experimenting with radium G the substance disappears in the very hands of the investigator, but that is not surprising if we keep in mind the fact that the quantity of material treated in these experiments is so infinitesimal that its presence can be proved only by its radioactivity. Whether it changes into a less active or an entirely inactive substance, it apparently disappears; its mass is too inconsiderable to be weighed, too minute to be detected by the microscope; there is no instrument by which its presence can be proved. Progress is possible in this direction only when we have a larger supply of radium. More radium is the emphatic demand of the medical man, the chemist, and the physicist. So far, therefore, we have been able to decide only indirectly into what radium F is transformed, but, through experiments which need not now be described, the conclusion has been reached that radium F must become lead.

It is an interesting fact that a large number of minerals which contain uranium always contain helium and radium A–F, and also lead in appreciable quantities. That surely favors the preceding supposition. The task is now to show that such a metal can have originated only from the mother substance—uranium—a portion of which in the course of centuries has passed through the transmutations named; so that now one such specimen contains not only uranium, grandmother, mother, and child, but nine generations following closely on each other. We could thus trace the genealogy of lead back to uranium without a break.

The next question is: Are the less radioactive substances to be considered as evidence of an earlier period of the earth's development; have such substances now reached a fixed, a final condition, and can there at present be shown a single example of the development and transmutation process, such as the other elements have passed through? Or, on the contrary, are all elements radioactive and still in a state of progressive development? We must not at once say "no" to these questions, for the reason that we have not yet observed radioactive qualities in these elements. We need only remember that it is easy to prove magnetic qualities in steel and iron, while in aluminum the apparent magnetic energy is a hundred million times less, and if we had only such substances as aluminum, copper, and zinc at our disposal we might not to-day understand the phenomena of electricity. After an opportunity to study these phenomena with

comparative ease in iron and steel, to learn their laws and to know what such an investigation requires, with ever finer and more accurate instruments we may be able to prove the existence of magnetic qualities in all substances. Shall we at some future time be able to do the same with radioactivity?

Experiments have already been made in this direction, and numerous physicists believe that their researches lead to the conclusion that all bodies are radioactive. They believe it can be proved that lead, zinc, etc., send out rays by which the air is made conductive. As corroboration of this, experiments are made to show that an electroscope inclosed in lead would lose its charge more rapidly than if inclosed in zinc. We must not lose sight of the fact, however, that our instruments are surprisingly sensitive, and that for that reason the slightest admixture of radioactive substances with those under examination might cause results similar to those observed.

I have referred to the fact that the presence of the radioactive emanation in all our springs shows the wide diffusion of radium in the earth. It shows, also, how easily one substance by coming in contact with another is affected by it. Elster and Geitel have now found proof that the radioactive emanation is everywhere present in the atmosphere, in the deepest excavations and shafts, as well as on the highest elevations, and that the appreciable quantity varies with rising and falling air pressure, dust, fog, rain, and snow. It will be easily understood how difficult this must render experiments in this direction, and how cautious one must be in reporting observations. From previous experiments it may be safely inferred that in the metals possessing radioactivity it is thousands of times weaker than in radium. It is certainly conceivable that the activity of these substances may be demonstrated by other methods and that they emit rays whose action has so far escaped us. Ten years ago such a suggestion would have been regarded as an idle dream, but such phenomena as wireless telegraphy, the Röntgen rays, and radioactivity have made us more cautious in criticism and bolder in hypothesis. Now that we have discovered the electron, have seen that an atom can subdivide into others, and have actually succeeded in observing one element transforming itself into another, it can not be regarded amiss if we venture to look for similar phenomona in the other elements. I do not hesitate to acknowledge that I class myself with those whose hope takes them much farther than this, even.

We must seek to gain power over the atomic processes, to control them as we now control the molecular processes. As we can to-day decompose water, and by reversing the operation can reproduce it, as we have learned to create thousands of organic substances, which were earlier believed to be beyond the power of man to produce, and

which were supposed to come into existence through certain life processes only, we must learn to separate the electron from the atom or to decompose it into a group of electrons, and perhaps out of these to build up a certain desired element. The solving of the first of these problems would become at once of great practical significance. Our control of the powers of nature would thus attain development beyond imagination, would be increased a million fold; for, however incredible it may sound, the processes with which we have hitherto been occupied are of minor importance compared with the atomic processes.

Are we to succeed in solving this problem? That the path toward the goal is long and difficult and not easily followed no one will deny. To learn to control thousandfold greater supplies of energy may well offer difficulties a thousandfold greater, but the notable results of the study of the powers of nature, increasing from decade to decade through the last century, inspire us with courage and arouse hope of great achievements in the new century already so full of promise. The naturalist of to-day is not pessimistic. If at first we are allowed to lift only a little corner of the veil with which nature has so carefully concealed the secret we pursue, we will not relinquish hope, but will

Attempt the end, and never stand to doubt;
Nothing's so hard but search will find it out.

RECENT ADVANCES IN WIRELESS TELEGRAPHY.[a]

By Chevalier G. Marconi, LL. D., D. Sc., M. R. I.

The phenomena of electro-magnetic induction, revealed chiefly by the memorable researches and discoveries of Faraday carried out in the Royal Institution, have long since shown how it is possible for the transmission of electrical energy to take place across a small air space between a conductor traversed by a variable current and another conductor placed near it, and how such transmission may be detected and observed at distances greater or less, according to the

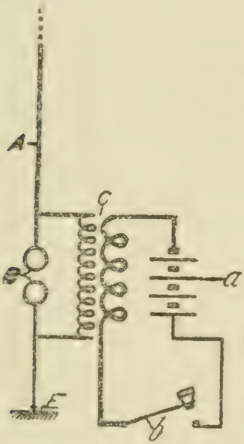


Fig. 1.

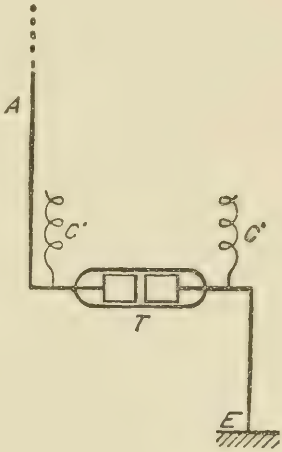


Fig. 2.

more or less rapid variation of the current in one of the wires, and also according to the greater or less quantity of electricity brought into play.

Maxwell, inspired by Faraday's work, gave to the world in 1873 his wonderful mathematical theory of electricity and magnetism, demonstrating on theoretical grounds the existence of electro-magnetic waves, fundamentally similar to but enormously longer than

[a] Abstract of paper read before the Royal Institution of Great Britain at its weekly evening meeting, Friday, March 3, 1905. Reprint of extract from transactions of the Royal Institution.

waves of light. Following up Maxwell, Hertz in 1887 furnished his great practical proof of the existence of these true electro-magnetic waves.

Building on the foundations prepared by these great men, the author carried out in 1895 and 1896 his first tests, with apparatus which embodied the principle on which long-distance wireless telegraphy is successfully worked at the present day.

This early arrangement is shown in figures 1, 2, and 3.

In figures 1 and 2 are shown diagrammatically the complete transmitting and receiving plants, and in figure 3 are shown the circuits of the receiving instruments.

The main feature of the system is the utilization of the earth effect by connecting both the transmitting and receiving instruments between earth and a raised capacity.

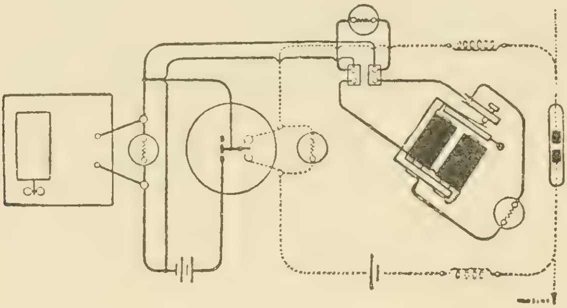


FIG. 3.

The later improvements introduced in the author's system of wireless telegraphy have been directed toward the following ends:

1. To obtain independence of communication or the prevention of interference between several neighboring stations.

2. To increase the distance of communication.

3. To increase the efficiency of the apparatus, its accuracy, and working speed.

One of the chief objections which is raised against wireless telegraphy is that it is possible to work only two or a very limited number of stations in the immediate vicinity of each other without causing mutual interference or producing a jumble by the confusion of the different messages. This objection appears to be much more serious to that section of the public which knows little or nothing of telegraphy in general than to telegraph engineers, who know that without organization and discipline the same interference would occur in the great majority of ordinary land telegrams. For example, there is an "omnibus" line between Cork and Crookhaven. On this line there are a dozen or more telegraph offices, all with their instruments joined up to the same wire running from the terminal stations. Now,

if any of these offices should proceed to send a message, say, to Cork, while this office is receiving another message from Crookhaven, it would cause an interference which would result in the confusion of the two messages, thus rendering them unintelligible. Any message sent on the line will affect all the instruments and can be read by all the other telegraph offices on the line; but certain rules and regulations are laid down and adhered to by the operators in the employ of the General Post-Office which make it impossible for one station to interfere with the rest. It is obvious that these same rules are applicable to every case in which a group of equally tuned wireless telegraph stations happen to be in proximity to each other.

Although in many instances untuned wireless telegraphy may prove of great utility, it is, however, clear that so long as some method of rendering stations completely independent of one another was not

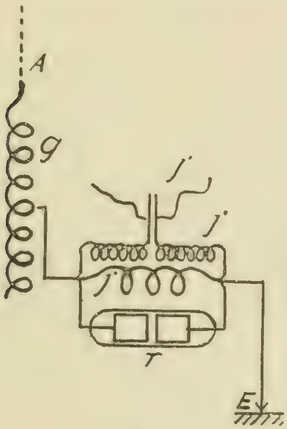


Fig. 4.

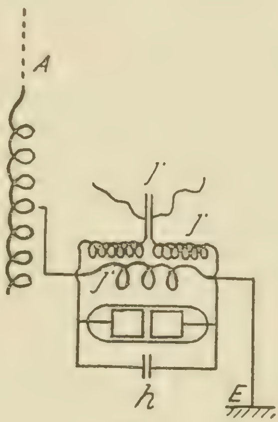


Fig. 5.

devised, a very important and effectual limit to the practical utilization of wireless telegraphy would be imposed.

The new method adopted by the author in 1898, of connecting a proper form of oscillation transformer in conjunction with a condenser (fig. 4), so as to form a resonator tuned to respond best to waves emitted by a given length of vertical wire, was a step in the right direction. This improvement was described by the author in a discourse which he had the honor to deliver in the royal institution in February, 1900.

Apart, however, from these improvements introduced into the receiving circuits, it had been for some time apparent that one difficulty in the way of obtaining syntonic effects was caused by the action of the transmitting wire. This straight rod or wire in which electrical oscillations are set up, forms, as is well known, a very good radiator or emitter of electric waves; but at the same time in all such

good radiators electrical oscillations set up by the ordinary spark-discharge method cease or are damped out very quickly by the electrical radiation, which removes very rapidly the small amount of their stored-up energy.

It is well known that if two tuning forks are taken having the same periods of vibration or note and one of them is set in motion by striking it sharply, waves or sounds will form in the air; and the other tuning fork, if in suitable proximity, will immediately commence to vibrate or sound in unison with the first.

Of course tuning forks have to do with air waves and wireless telegraphy with ether waves, but the action in both cases is analogous.

There is one essential condition which must be fulfilled in order that a well-marked tuning or electrical resonance may take place, and it is based on the fact that what we call electrical resonance,

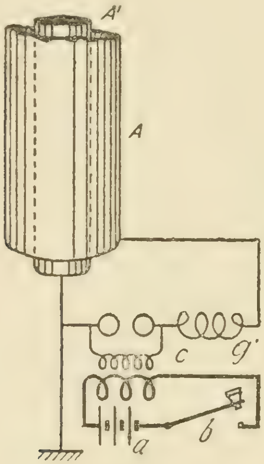


FIG. 6.

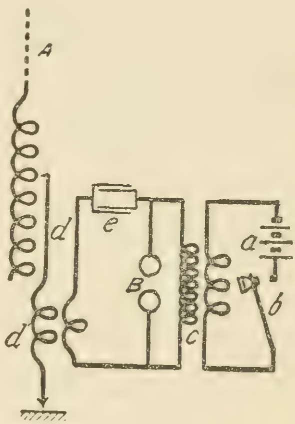


FIG. 7.

like mechanical resonance, depends essentially upon the accumulated effect of a large number of feeble impulses properly timed. Tuning can only be achieved if a sufficient number of these timed electrical impulses reach the receiver.

Over four years ago the author obtained satisfactory results by increasing the electrical capacity of the radiating and resonating conductors by arranging them at each station in the form of two concentric cylinders, or in other forms of closely adjacent conductors. The electrical capacity of such conductors, as shown in fig. 6, is very large compared with that of a single vertical wire, with the result that the amount of electrical energy stored up in the system referred to in the first case is much larger, and does not radiate or get away in one or two waves, but forms a train of timed impulses which subsist for a certain time, which is what is required.

An arrangement consisting of a circuit containing a condenser and a spark gap, fig. 8, constitutes a very persistent oscillator. Sir Oliver Lodge has shown that by placing it near to another similar circuit it is possible to demonstrate effects of tuning. The experiment is usually referred to as "Lodge's syntonic jars," and is extremely interesting, but, as Lodge himself points out in his book, the Work of Hertz, a closed circuit such as this is "a feeble radiator and a feeble absorber, so that it is not adapted for action at a distance."

If, however, such an oscillating circuit is inductively associated with one of the author's elevated radiators, it is possible to cause the energy contained in the closed circuit to radiate to great distances, the essential condition being that the natural period of electrical oscillation of the radiator should be equal to that of the nearly closed circuit.

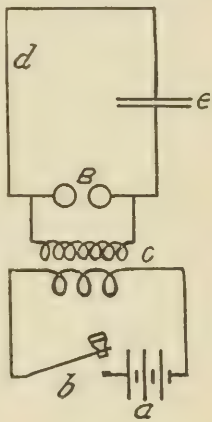


FIG. 8.

All the latest syntonic transmitting arrangements are based on modifications of this combination.

The general arrangement is indicated in fig. 7.

The arrangement for syntonizing or tuning the receiving stations are shown in fig. 5. Here is shown the usual vertical conductor connected to earth through the primary of a transformer, the secondary circuit of which contains a condenser, which is connected across the coherer or detector. In this case, also, it is necessary that the period of electrical oscillations of the vertical wire, which includes the primary of the transformer and earth connection, should be equal to that of, or in tune with, the secondary circuit of the said transformer, which circuit includes a condenser. Therefore, in order that a transmitter (fig. 7) should be in tune with the receiver (fig. 5), it is necessary that the periods of oscillation of the several oscillating circuits at both stations should be equal, or very approximately so.

It is easy to understand that if we have several stations, each tuned to a different period of electrical oscillation, the periods of resonance of which are known, it will not be difficult to transmit messages to any one of them without the signals being picked up by the other stations for which they are not intended. It is obvious that the greater the difference in periods of the oscillation or tune between two stations, the smaller will be the possibility of tapping and mutual interference.

It is also possible to connect to one sending wire, through the connections of different inductances, several differently tuned transmitters, and to a receiving wire a number of corresponding receivers, as is shown in figs. 9 and 10.

It was possible nearly five years ago to send different messages simultaneously without interference, the messages being received on differently tuned receivers connected to the same vertical conductor.

This result was described in the Times of October 4, 1900, by Professor Fleming, who, in company with others, witnessed the test.

A recent improvement introduced in the method of tuning the receiver is that shown in fig. 11.

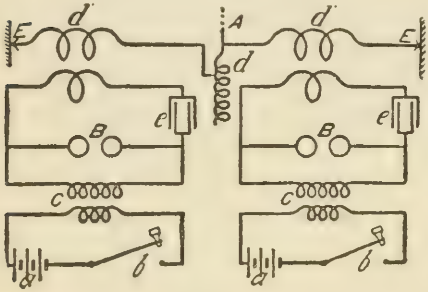


FIG. 9.

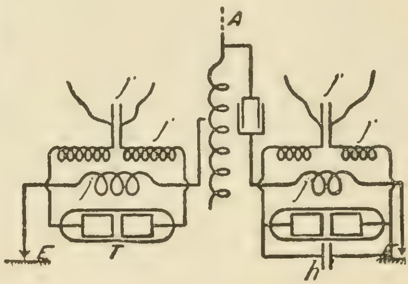


FIG. 10.

There exists at present among the large section of the public considerable misconception as to the feasibility of tuning or syntonizing wireless telegraphic installations, and also as to what is generally termed "the interception of messages." According to the accepted understanding, "intercepting" a message means or implies securing by force, or by other means, a communication which is intended for somebody else, thereby preventing the intended recipient from receiving it. Now, this is just what has never happened in the case of wireless telegraphy. It is quite true that messages are, and have been, tapped or overheard at stations for which they are not intended, but this does not by any means prevent the messages from reaching their proper destination. Of course, if a powerful transmitter giving off strong waves of different frequencies is actuated near one of the receiving stations, it may prevent the reception of messages, but the party working the so-called interfering station is at the same time unable to read the message he is trying to destroy, and therefore the message is not, in the popular sense of the word, "intercepted." It should be remembered

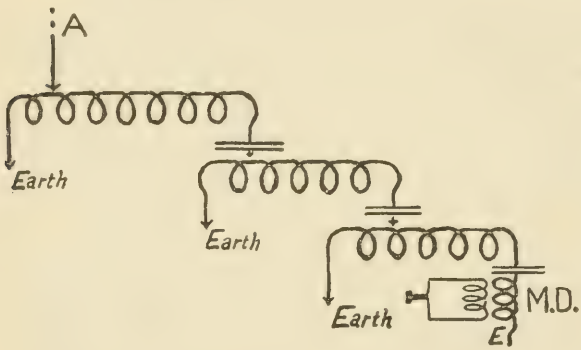


FIG. 11.

that any telegraph or telephone wire can be tapped, or the conversation going on through it overheard, or its operation interfered with. Sir William Preece has published results which go to show that it is possible to pick up at a distance on another circuit the conversation which may be passing through a telephone or telegraph wire.

Up to the commencement of 1902 the only receivers that could be practically employed for the purposes of wireless telegraphy were based on what may be called the coherer principle—that is, the detector, the principle of which is based on the discoveries and observations made by S. A. Varley, Professor Hughes, Calsecchi Onesti, and Professor Branly.

Early in that year the author was fortunate enough to succeed in constructing a practical receiver of electric waves, based on a principle different from that of the coherer. Speaking from the experience of its application for over two years to commercial purposes, the author is able to say that, in so far as concerns speed of working, facility of adjustment, reliability, and efficiency when used on tuned circuits, this receiver has left all coherers or anticoherers far behind.

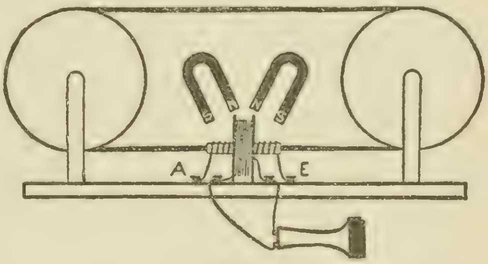


Fig. 12.

The action of this receiver is in the author's opinion based upon the decrease of magnetic hysteresis, which takes place in iron when under certain conditions this metal is exposed to high frequency oscillations of Hertzian waves.

It is constructed in the following manner and is shown in fig. 12.

On an insulating sleeve surrounding a portion of a core, consisting of an endless rope of thin iron wires, are wound one or two layers of thin insulated copper wires. Over this winding insulating material is placed, and over this again another longer winding of thin copper wire contained in a narrow bobbin. The ends of the windings nearer the iron core are connected one to earth and the other to the elevated conductor, or they may be joined to any suitable syntonizing circuit, such as is now employed for syntonic wireless telegraphy. The ends of the longer winding are connected to the terminals of a suitable telephone. A pair of horseshoe magnets are conveniently disposed for magnetizing the portion of the core surrounded by the windings, and the endless iron core is caused to move continuously through the windings and the field of the horseshoe magnets.

This detector is and has been successfully employed for both long and short distance work. It is used on the ships of the Royal Navy and on all trans-Atlantic liners which are carrying on a long-distance

news service. It has also been used to a large extent in the tests across the Atlantic Ocean.

As already stated, the adoption of this magnetic receiver was the means of bringing about a great improvement in the practical working conditions of wireless telegraphy by making it possible to do away with the troublesome adjustments necessary when using coherers, and also by considerably increasing the speed at which it is possible to receive, the speed depending solely on the ability of the individual operators. Thus a speed of over 30 words a minute has been easily attained with the apparatus as shown in fig. 12.

This form of magnetic receiver, however, presented a disadvantage which some people considered very important—of being able to bring about only an audible reproduction of the signals in a telephone, and consequently ineffective for actuating a recording instrument, such as would leave a documentary proof in the form of Morse signals received and inscribed on tape.

When the author had the honor to deliver his last lecture at the Royal Institution, he expressed a hope that by means of this magnetic receiver it might be possible to work a recording instrument, and he is glad to be able to announce that he has recently been able to construct a magnetic receiver that will work a relay and a recorder.

The causes which prevented the author's earlier type of magnetic receiver from working a relay were the rapidity and alternating character of the current induced by the effect of the oscillations on the iron. This current or impulse is so sudden that, although it proves to be suitable in producing a sound or click in a telephone diaphragm, it is far too quick to impart any appreciable movement to the comparatively heavy tongue of a relay, and in that way to allow a current to work a recording or other instrument. By modifying the circuits, especially by increasing their length and by the use of a particular quality of iron, the author has been able to obtain an impulse from the magnetic receiver, which is capable of working a recording instrument.

The instrument is eminently adapted for receiving messages from stations such as Poldhu, where the length of wave radiated is considerable.

The advantages of this receiver over the coherer system of receiver are very great.

In the first place, it is far more simple, requires far less attention, is absolutely reliable and constant in its action, and possesses a low and unvarying resistance. But the chief advantage lies in the fact that with this receiver it is possible to attain a very high speed of working.

The speed of the author's earlier form of magnetic receivers was

limited to the rate at which the operator could read by sound. So for as speed is concerned, however, this new detector is not dependent upon the ability of the operator. It is possible to use an automatic transmitter to send messages at the rate of 100 words a minute, and the messages will be picked up and recorded quite clearly and distinctly by means of this new form of receiver.

The author here gave a demonstration of wireless transmission and reception by means of high speed "Wheatstone" instruments lent by the General Post-Office, used in conjunction with his magnetic receiver.

This form of recording receiver has been satisfactorily worked over a distance of 152 miles over land, and will shortly be employed in connection with the new transatlantic stations.

In conjunction with Professor Fleming, the author has recently introduced further improvements which greatly increase the efficiency of the apparatus, but which he is not at present free to describe. The author here demonstrated the effect of the improvement by means of a galvanometer, showing the deflection without and with the new device. The author also exhibited and explained Doctor Fleming's cymometer for measuring the length of waves used in wireless telegraphy.[a]

A very considerable amount of public interest has been centered during the last few years on the tests and experiments in which the author has been engaged in investigating the possibilities of wireless telegraphy over very great distances, and especially on the tests which are being carried out across the Atlantic Ocean.

The facility with which distances of over 200 miles could be covered with the author's apparatus as long ago as 1900, and the knowledge that by means of syntonic devices mutual interferences could be prevented, led the author to advise the construction of two large power stations, one in Cornwall and the other in North America, in order to test whether, by the employment of much greater power, it might not be possible to transmit messages across the Atlantic Ocean.

On the erection of these stations very extensive tests and experiments were carried out during the latter part of 1902. These tests were greatly facilitated by the courtesy of the Italian Government, which placed a 7,000-ton cruiser, the *Carlo Alberto*, at the author's disposal. During these trials the interesting fact was observed that, unlike what occurs with moderate power-transmitting stations, the effect of intervening land or mountains between the sending and receiving apparatus does not bring about any considerable reduc-

[a] Dr. J. A. Fleming, "On an instrument for the measurement of the length of long electric waves and also small inductances and capacities," Proc. Roy. Soc. Lond., Vol. LXXIV.

tion in the distances over which it is possible to communicate; this result being due, no doubt, to the much greater length of wave radiated by the big elevated conductor of the long-distance stations, compared with the shorter wave-length radiated by the smaller and less powerful installations. Thus messages were received from Poldhu at the positions marked on the map (fig. 13), which is a copy of the map accompanying the official report of the experiments. These positions, at which signals were received direct from Poldhu, are in the Baltic near Sweden, at Kiel, the North Sea, the Bay of Biscay, also Ferrol, Cadiz, Gibraltar, Sardinia, and Spezia. Messages were received distinctly in these places from Cornwall, although, in the Baltic,

Fig. 13.

the whole of England, the Netherlands, and part of Germany and Scandinavia lay between Poldhu and the *Carlo Alberto*. Also, at Cadiz and Gibraltar the whole of Spain intervened; and at Spezia and Cagliari, in the Mediterranean, the whole of France, including the Alps, lay in a direct line between the two stations.

After these experiments the *Carlo Alberto* was sent back from the Mediterranean to Plymouth, and thence conveyed the author to Canada; and in October, 1902, signals from Poldhu were received on board ship throughout the voyage up to a distance of 2,300 miles.

In December, 1902, messages were exchanged between the stations at Poldhu and Cape Breton, but it was found that communication was better from Canada to England than in the opposite direction.

The reason for this is to be attributed to the fact that, owing to the support and encouragement of the Canadian government, the station at Cape Breton had been more efficiently and more expensively equipped; whilst as regards Poldhu, owing to the uncertainty as to what would be the attitude of the British Government at that time toward the working of the station, the author's company was unwilling to expend large sums of money for the purpose of increasing its range of transmission.

As, however, messages were sent with ease and accuracy from Canada to England, the author considered it his duty to send the first messages to their Majesties the Kings of England and Italy, both of whom had previously given him much encouragement and assistance in his work. The author was thus enabled to announce that the transmission of telegraphic messages across the Atlantic Ocean without the use of cable or wire was an accomplished fact. Messages were also sent to His Majesty from Lord Minto, the Governor-General of Canada, who had taken a considerable interest in the author's early experiments in Canada. Officers delegated by the Italian Government and a representative of the London Times were present at the transmission of the messages, and over 2,000 words were sent and correctly received in the presence of these Government delegates.

Further tests were then carried out at the long-distance station erected at Cape Cod, in the United States of America, and a message from President Roosevelt was successfully transmitted from this station to His Majesty the King.

In the spring of 1903 the transmission of news messages from America to the London Times was attempted, and the first messages were correctly received and published in that newspaper. A breakdown in the insulation of the apparatus at Cape Breton made it necessary, however, to suspend the service, and, unfortunately, further accidents made the transmission of messages unreliable, especially during the spring and summer. In consequence of this, the author's company decided not to attempt the transmission of any more public messages until such time as a reliable and continuous service could be maintained and guaranteed under all ordinary conditions.

It is curious to note that the transmission of messages across the Atlantic appeared to be much easier during the winter months of December, January, and February than during the spring and summer, but no serious difficulties were encountered before April. These were partly caused by the insulation of the aerial not being so good during the damp spring weather, when the snow and ice are melting and thawing, as at this period the insulation is much more difficult to maintain in an efficient condition than during the dry and crisp Canadian winter.

A new station, supplied with more powerful and more perfect apparatus, is in course of erection, and the author has not the slightest doubt but that in a very short time the practicability and reliability of transatlantic wireless telegraphy will be fully demonstrated.

In connection with these very powerful stations it is interesting to observe that the fact which the author had noticed in 1895 and which he expressed in his patent of June 2, 1896, that "the larger the plates (or capacities) of the receiver and transmitter and the higher from the earth the plates are suspended the greater the distance that it is possible to communicate at parity of other conditions," still holds good, and therefore the elevated conductors at these stations are much larger and higher than those used at the smaller power stations. The potential to which they are charged is also very much in excess of that used at the short-distance stations.

Pending the reconstruction of these long-distance stations, valuable tests have been carried out, and daily commercial work is carried on over distances of about 2,000 miles. In October, 1903, it was found possible to supply the Cunard steamship *Lucania* during her entire crossing from New York to Liverpool with news transmitted direct to that ship from Poldhu and Cape Breton.

Since June a regular long-distance commercial service has been in operation on certain ships of the Cunard Steamship Company, which ships, throughout their voyage across the Atlantic, receive daily news messages collected for transmission by Messrs. Reuter in England, and by the Associated Press in America. At present five trans-Atlantic steamships are thus publishing a daily newspaper containing telegraphic messages of the latest news.

The practical and experimental work carried out in connection with the long and short distance stations has afforded valuable opportunities for noting and studying various unknown and unexpected effects of the condition of space on the propagation of electromagnetic waves.

The author being able to avail himself of the daily reports of over 70 ships and 50 land stations, the chances of error from what might be termed accidental results are reduced to a minimum. Thus it is interesting to observe that the difference between the propagation of the wave by day and by night is only noticeable in the case of long-distance stations; or, in other words, where a considerable amount of energy is forced into the transmitting aerial wires. For instance, all the short-distance ship-to-shore stations having a range of about 150 miles averaged the same distance of communication by day as by night; but the long-distance stations, such as Poldhu, Cape Breton, and Cape Cod, as originally constructed, averaged by day two-fifths of the distance covered by night.

The opinion has been expressed that the reason for shorter distances being covered by day is due to the electrons propagated into space by the sun, and that if these are continually falling like a shower upon the earth, in accordance with the hypothesis of Professor Arrhenius, then that portion of the earth's atmosphere which is facing the sun will have in it more electrons than the part which is not facing the sun, and therefore it may be less transparent to long Hertzian waves.

The full scientific explanation of this fact has not yet been given, but Prof. J. J. Thomson has shown in an interesting paper in the Philosophical Magazine[a] that if electrons are distributed in a space traversed by long electric waves, these will tend to move the electrons in the direction of the wave, and will therefore absorb some of the energy of the wave. Hence, as Professor Fleming has pointed out in his Cantor lectures delivered at the Society of Arts, a medium through which electrons or ions are distributed acts as a slightly turbid medium to long electric waves.

In fact, clear sunlight or blue skies, though very transparent to light-waves, may act as a fog to Hertzian waves. Apparently the amplitude of the electrical oscillations radiated has much to do with the interesting phenomenon, for the author has found that if a considerable amount of power is applied to the radiating apparatus of the so-called short-distance stations, the difference between the range of transmission by night and by day becomes at once apparent, although no difference is made in the wave length radiated.

A curious feature of what may be called the daylight effect is the suddenness with which it may cut off the signals at great distances. These do not, as might be supposed, die off gradually as daylight increases, but seem to fade away rapidly, and disappear entirely within the space of about two minutes.

The author does not for a moment think that this daylight effect will prove to be a serious drawback to the practical application of long-distance wireless telegraphy, as its result amounts to this, that rather more power is required by day than by night to send signals by means of electric waves over long distances.

It has been stated that one of the serious objections to wireless telegraphy lay in the fact that no means existed for directing the energy emitted by the stations. If we assume this fact to be correct, we certainly find that, if it presents certain disadvantages, it also presents many perhaps counterbalancing advantages. For example, if a cable is laid between England and Canada it can only serve for communication between these two countries; but if a wireless connec-

[a] Vol. IV, Series 6, August, 1902.

tion is established between two such countries the stations may be instantly used in time of war, or in any other emergency, to communicate with other stations, situated say, at Gibraltar, the West Indies, or some inland point in North America, and also, if necessary, with war ships carrying apparatus tuned to the waves such stations radiate. By means of syntony, although the energy can not be directed in one direction, it can, however, be picked up at certain distances only by certain tuned receivers, as occurs now with the ships crossing the ocean. Fifty of these ships carry wireless apparatus, but only five of them have the instrument tuned to receive the long-distance news messages sent from Poldhu; and, as a matter of fact, these messages are received only by those five specially tuned ships.

Before concluding, it may not be out of place to give a few details as to the practical uses to which the author's system of wireless telegraphy has already been put.

There are now over 80 British and 30 Italian war ships equipped. A number of these war ships are fitted with long-distance apparatus, and are therefore able to keep in touch with England when far out on the Atlantic, at Gibraltar, and in the Mediterranean. Admiral Lord Charles Beresford has authorized the author to say that during the last cruise of the Channel Fleet from Gibraltar to England they had no difficulty whatever in receiving messages from Cornwall during the entire voyage by means of special long-distance receivers.

Seventy liners, belonging respectively to England, Italy, France, Germany, Holland, Belgium, and the United States, are fitted with the author's apparatus, and are engaged in carrying on commercial work for the benefit of passengers between ship and ship and between ship and shore; and for this latter purpose there are over 50 land stations with which to communicate. During 1904, 67,625 commercial messages were sent and received at the ship and shore stations controlled by the author's company.

It is also used as a branch of the Italian telegraphic system for ordinary commercial purposes across the Adriatic Sea, namely, between Bari (in Italy) and Antivari (in Montenegro), and in the Straits of Messina at Messina, Reggio, and Giovanni. Also, in connection with the British post-office, from Cornwall to the Scilly Islands, on the not infrequent occasions of the breaking down of the cables.

As to the future of wireless telegraphy, the author expresses his confidence in its ability to furnish a more economical means for the transmission of telegrams from England to America and from England to the colonies than the present service carried on by the cables.

It is true that many scientific men are dubious of the practicability of sending electric waves to great distances. Others are not. On

a recent memorable occasion at Glasgow University, Lord Kelvin publicly stated that he not merely believed that messages could be transmitted across the Atlantic, but that some day it would be possible to send messages to the other side of the globe. Apart from the practical and economical possibilities of this step, when realized, the transmission of messages to the Antipodes would open up the possibility of carrying out tests of very great scientific interest. For example, if transmission to the Antipodes were possible, the energy ought to go over or travel round all parts of the globe from one station to the other, and perhaps concentrate at the Antipodes, and in this way it might perhaps be possible for messages to be sent to such distant lands by means of a very small amount of electrical energy, and, therefore, at a correspondingly small expense.

REVISIONS OF THE THEORY OF ELECTROLYSIS.[a]

By Henry S. Carhart, LL. D.

No subject in the whole domain of theoretical electricity possesses more interest to the electrochemist than the theory of the decomposition of aqueous solutions of salts and acids through the agency of an electric current. For more than a hundred years scientific attention has been converged on it, for it has presented problems both of unusual interest and of unusual difficulty. Its development has not been one of uninterrupted progress, but rather one of leaps and bounds, alternating with seasons of suspended animation. Even with the noteworthy additions of the past twenty years, it can not be said that all difficulties have yet been resolved. We are in little danger of so completely clearing up the entire field that nothing shall be left for posterity.

An historical review of this subject, biased it may be by perspective and distorted by the disproportionately large visual angle under which we view recent events, may yet give us more respect for the achievements of the past and less unreserved satisfaction with the advances of our own times.

The earliest record of observed electrolysis dates back of the invention of Volta's dry pile and "crown of cups." The decomposition of water by electrical means was described by van Troostwijk and Deimann in 1789. It was accomplished by sending a series of electric discharges through water in a narrow glass tube between gold wires whose ends were an inch and a half apart. The tube was placed vertically, and when the end of the upper wire became uncovered the spark caused the explosive reunion of the mixed gases. These experimenters concluded, contrary to the opinion of many of their scientific contemporaries, that both the hydrogen and the oxygen were obtained from the decomposition of water and that

[a] Presidential address delivered at the seventh general meeting of the American Electrochemical Society, held at Boston, Mass., April 25, 1905. Here reprinted from Transactions of the American Electrochemical Society, Vol. VII, Philadelphia, 1905.

water consisted of a union of these two gases only. They cited both the synthesis and the analysis taking place in their experimental tube as proofs of their view. But the question as to the manner in which electricity acts to effect the decomposition remained unanswered. They did not obtain the two gases separately, but mixed in the glass tube. An enormous number of discharges were said to be necessary to produce an appreciable volume of mixed gases—14,600 for one-third of a cubic inch.

A little later Ritter found that 50 or 60 discharges from a Leyden jar through a solution of silver nitrate between silver wires gave a visible deposit of metallic silver on the negative electrode. By reversing the poles this deposit disappeared, and at the same time a new deposit formed on the other wire.

It is therefore obvious that the scientific world was prepared to accept electrolytic decomposition when Volta disclosed his invention of the dry pile and the voltaic battery, or "crown of cups." This disclosure was made in a letter to Sir Joseph Banks, president of the Royal Society of London, dated March 20, 1800. Before this letter was published in the Philosophical Transactions its contents had become known to London physicists, and Nicholson and Carlisle had decomposed water by means of Volta's pile. Carlisle made the acute observation that when a drop of water was placed on the upper plate of the pile to improve the contact between it and the wire of the external circuit, gas was given off; and Nicholson recognized the presence of hydrogen when the wire used was steel. These and similar facts induced them to send the electric current from a pile of 36 pairs through river water between brass wires in a glass tube half an inch in diameter. A fine stream of gas bubbles was at once given off from the negative electrode. One-fifteenth of a cubic inch was obtained in an hour and a half, and when this was mixed with an equal volume of air the mixture exploded on the approach of a lighted wax taper.

Although these observers expected the decomposition of water, they were not prepared for the astonishing fact that, while the hydrogen appeared at the exposed end of one of the wires, the oxygen appeared only at the end of the other, nearly 2 inches distant. This phenomenon was to its discoverers inexplicable. They made the very relevant and acute remark that this new phenomenon "appears to show perhaps a general law of the action of electricity in chemical processes." The explanation of this remarkable fact has ever since engaged the attention and best endeavors of science.

It is worthy of attention also that Nicholson and Carlisle observed that chemical action takes place in a voltaic cell when it functions as a source of current. In other words, they recognized that a voltaic cell is also an electrolytic cell. This is the first of many facts which

tell against Volta's contact theory of the electromotive force of a voltaic cell. Volta himself asserted that the chemical actions going on in a voltaic cell have practically no essential significance.

In this same celebrated year of 1800 Cruikshank decomposed lead acetate between silver wires. A minute or two after connection was made he observed lustrous metallic lead crystals on the negative electrode, while gas was released at the positive. Cruikshank called attention to the fact that only liquids containing oxygen conduct electricity, and he appears to have concluded that electricity seizes on the oxygen and transports it invisibly to the positive pole. Not so far removed from this conception is the present view that the oxygen conveys an electric charge rather than that the charge conveys the oxygen.

The separate appearance of the two products of decomposition at the electrodes was the most noteworthy, and at the same time the most inexplicable fact of electrolysis to all the chemists and physicists of the day. An unknown correspondent in Nicholson's Journal expressed himself as follows:

> I should like to inquire how it can happen in any system that the two components of water can be caused to appear at such a distance from each other. Does the hydrogen from the dissociated particles of water at the zinc side of the pile fly from it at the instant when the oxygen is liberated there? If that is so, why does not one see the gas bubbles on the way? Or does the oxygen migrate from the silver side to the zinc side? Or are there two streams at once?

It should be remembered that Volta attached an extra zinc plate to the silver at the positive end and an extra silver plate to the zinc at the negative end, both in the case of his dry pile and crown of cups or voltaic battery. Hence, in the early literature the zinc side means the positive and the silver the negative.

Sir Humphry Davy was early in the field of electric research, and at once distanced all his English confrères by the number and importance of his detail discoveries. In particular at the outset he obtained oxygen and hydrogen in different tubes separated in the circuit by the interposition of his own person as a conductor, and he proved conclusively that the two gases are evolved in the same relative proportion in which they exist as elements in water. But Sir Humphry Davy added little to the theory of electric action in electrolysis. Near the close of one of his papers published in December, 1800, he remarks:

> On these facts I shall not presume to speculate * * *. Many observations must be collected, probably, before we shall be able to ascertain whether water is decomposed in galvanic processes. Supposing its decomposition, we must assume that at least one of its elements is capable of rapidly passing in an invisible form through metallic substances, or through water and many connected organic bodies, and such an assumption is incommensurable with all known facts. But a short period has elapsed since philosophers beheld

with wonder solid and fluid substances assuming new modes of existence in different gases. Do not the new phenomena of galvanism authorize us to hope that at no very distant time they will behold even those gases undergoing novel changes and existing in new and now unknown forms?

The diffuseness and lack of concreteness of ideas in those early days of the science, before the time of Ohm's law, are strikingly illustrated in the following extract from a syllabus of a course of lectures delivered by Davy in the theater of the Royal Institution in January, 1802:

> The agency of the galvanic influence which occasions chemical changes in water and communicates shocks to the living body is probably in some measure distinct from that agency which produces sparks and the combustion of bodies. The one appears, all other circumstances being similar, to have little relation to surface in compound circles, but to be great in some unknown proportion as the series are numerous. The intensity of the other seems to be as much connected with the extension of the surface of the series as with their number.

Davy was not at that time able to distinguish between electromotive force or electric pressure and strength of current.

The long contest waged between the supporters of the contact theory of electric action in a voltaic couple and the chemical theory is briefly alluded to in this same syllabus, without any clear intimation of the position taken by Sir Humphry himself:

> M. Volta has supposed that an electrical current is always produced by the mere contact of certain different conductors of electricity. But many of the British philosophers have denied this position, accounting for galvanism from the destruction of the equilibrium of electricity in galvanic circles in consequence of the chemical agencies of the different bodies composing them.

On November 20, 1806, Davy read before the Royal Society a Bakerian lecture on "Some chemical agencies of electricity." In this lecture he takes a decided position against the chemical theory of electrical excitation held by many British philosophers. He says:

> The general ideas advanced in the preceding pages are evidently directly in contradiction to the opinion advanced by Fabroni, and which, in the early stages of investigation, appeared extremely probable, namely, that chemical changes are the *primary* causes of the phenomena of galvanism.
>
> Before the experiments of M. Volta on the electricity excited by the mere contact of metals were published, I had to a certain extent adopted this opinion; but the new facts immediately proved that another power must necessarily be concerned.

In this same lecture we find suggestions by this distinguished philosopher harmonizing with the celebrated theory of Grotthus; but no credit is due to Davy for these suggestions, because Grotthus published his theory in the year 1805 in Rome under the title: "Memoire sur la decomposition de l'eau et des corps, qu'elle tient en dissolution, a l'aide, de l'électricité galvanique." A second edition followed

the next year, and the memoir was also published in the Annales de Chimie in 1806. Sir Humphry says:

> It is very natural to suppose that the repellent and attractive energies are communicated from one *particle to another particle* of the same kind, so as to establish a conducting chain in the fluid; and that this is really the case seems to be shown by many facts * * *.
>
> In the case of the separation of the constituents of water, and of solutions of neutral salts forming the whole of the chain, there may possibly be a succession of decompositions and recompositions throughout the fluid.

Ostwald says (Elektrochemie, p. 307) that the different theories proposed to explain the separate evolution of the products of electrical decomposition vied with one another in improbability, and no one of them was free from the most serious objections. When at length one view met with general acceptance it was not so much because of its unconditional excellence as because it was at least relatively the best of all.

Hear the account of Grotthus himself relating to the origin of his theory. He says:

> Volta's pile, which made the genius of its inventor immortal, is an electrical magnet, of which each element—that is, each pair of plates—has both a positive and a negative pole. The consideration of this polarity has suggested to me the idea that a similar polarity might form between the molecules of water when it is acted on by this same electrical agent; and I must confess that this was for me a gleam of light.

Freiherr von Grotthus was a most interesting character. At the age of a year and a half the death of his father left him to the care of his mother, and he lived with her on her landed estate in Lithuania, near the borders of the Baltic province of Kurland, till his seventeenth year. The taste for science developed in him at an early age, but it was stifled in the most brutal and unsympathetic manner by his teacher, who had neither the taste nor the intelligence for the studies to which the genius of Grotthus inclined. In the year 1803, at the age of 18, he went to Leipzig to study, and after six months there he betook himself to Paris, where he listened to the lectures of the most distinguished philosophers of the time. The threatened war between France and Russia compelled him to leave Paris, and he hastened to Naples, where he remained till the end of the year 1805. Through his fortunate acquaintance there with a distinguished English physician named Thomson, who was the owner of a small galvanic apparatus, our young natural philosopher was enabled to repeat the experiments of Professor Pacchiani, which were then exciting much attention. The result was his theory of electrolysis, first published in 1805, when its author was not more than 20 years of age, a theory which held sway for nearly three-quarters of a century and

which has forever linked his name with the history of electrochemistry.

Under more favorable conditions of birth, education, and surroundings Grotthus might have become one of the most distinguished investigators of his time. But in the autumn of 1807 he felt compelled to return to his ancestral estate and to busy himself with the duties of manager. Here in the country, in a remote angle of Lithuania, for the most part without literary associates, and lacking often the most essential means of research, he wrung from nature some of her well-concealed secrets and wrote nearly all his contributions to science.

For years he suffered unspeakably from an incurable organic malady. The trouble increased from day to day, and finally reached such an acute stage that he was brought to the rash decision to sever voluntarily the thread of life. He died in 1822 at the age of 37.

The Grotthus theory of the mechanism of electrolysis does not respond, as we now know, to the facts of later discovery. But since for the first time it made comprehensible the physical possibility of the phenomena of electrolytic decomposition it has enduring value.

Grotthus conceived that a species of polarization is set up in the water by electrical agency, so that the positively charged elements are turned toward the negative electrode and the negatively charged ones in the other direction. Also, that at the moment of separation of the oxygen and hydrogen from each other a division of their natural charge of electricity takes place, in some way not explained. Attractions and repulsions follow; also the continuous movement of two streams of charged particles in opposite directions, through the process of molecular interchanges or the exchange of partners whose conjugal bond is chemical affinity. Grotthus does not appear to have got the conception that a current in an electrolyte is the convection of positive and negative charges in opposite directions, but his theory was directed toward the explanation of the most obvious and novel fact that the products of the decomposition appear at widely distant points. He distinctly remarks that the process, as he conceives it, involves decomposition at the electrodes only, where the current passes between the electrode and the electrolyte. He says:

> I conclude, therefore, that if it were possible to produce in water a current of galvanic electricity so that it should describe in it a complete circuit, all the molecules of the liquid which are in this circuit would at the same instant be decomposed and again reformed; whence it follows that this water, although it underlies the action of galvanism, would still always remain water.

Grotthus had no consistent idea of the relation between the charges carried by the components of a molecule and the passage of a current. The current appeared to him only to align the molecular components,

and the resulting molecular cleavages and re-formations were due to the attraction and repulsion between the electric charges, or their polarity. His conception was crude and imperfect compared with the corresponding concepts of the present time. But it showed at least that the phenomena of electrolysis take place by a conceivable process. If it did not satisfy all intellectual demands, it quieted clamor and bridged the gulf between the known and the inexplicable. It was indeed a gleam of light that has never been effaced; and we owe an everlasting debt of gratitude to the farmer philosopher of Lithuania.

Grotthus gave a vivid picture of the chief phenomenon of electrolysis, the appearance of the separated constituents at the electrodes only. The knowledge of his time scarcely reached beyond this one fact. It was not long, however, before new observations were made, which could with difficulty be fitted into his picture.

The essential fact which the theory of Grotthus was incompetent to answer satisfactorily was that the smallest electromotive force may produce a current through an electrolyte, and the strength of this current follows Ohm's law.

Grotthus assumes that the application of an electromotive force to the electrodes gives rise to a polarized condition of the molecules, and that at the instant of the separation of the hydrogen and oxygen, for example, a separation of their natural charge of electricity takes place, either through contact or friction; so that one part becomes electropositive and the other electronegative. This perhaps means that the normal condition of an electrolyte is one of equilibrium with rigidly combined molecules. Grotthus did not appear to conceive of the cleavage of a polarized molecule until current passed.

From the time of Grotthus there was a long pause of fifty years in the theory of electrolysis, for no important step was taken until Clausius, in 1857, published his profound modification of the Grotthus theory. Clausius's study of the kinetic theory of heat prepared him to apply similar principles to the interpretation of electrolytic phenomena. He leaves no doubt about his meaning; his conceptions are always clear and clearly expressed. I will let him speak for himself:[a]

Let there be a liquid, consisting wholly or in part of electrolytic molecules; and let it be assumed that these molecules are arranged in the natural condition of the liquid in any definite manner in which they persist, so long as no foreign force acts on them, while the individual molecules oscillate perhaps about their positions of equilibrium, but are unable to get quite away from them. Further, let an attraction be assumed between two part-molecules, as there must be in every possible arrangement, and let two part-molecules be

[a]Annal. d. Physik, vol. 101, 1857.

bound together into a whole molecule and, therefore, very near together; then the attraction binding them together is greater than the attraction between the positive part-molecule of one complete molecule and the negative of another. If now an electric force acts within this mass, and seeks to urge the positively electrified part-molecules in one direction and the negatively electrified ones in the other, then the question arises what influence this electric force must exert on the behavior of the molecules.

Inasmuch as the molecules are assumed to be capable of rotation, the first effect would plainly be to turn all of them in the same manner, so that the two oppositely electrified portions of each complete molecule would be turned in the direction in which they are urged by the acting force. Further, the force would seek to separate the part-molecules united in a whole or complete one and to move them in opposite directions; and if this motion ensues, then the positive part-molecule of one whole one would meet the negative of the following and would combine with it. But now, in order that the once united part-molecules may be separated, the attraction which they exercise on each other must be overcome. Therefore a force of definite strength is necessary, and one is thus led to the conclusion that so long as the force acting on the conductor does not have this strength no decomposition whatever can take place, and that, on the contrary, if the force is increased to the requisite strength very many molecules must be decomposed at the same time, since they are all under the influence of the same force and have precisely the same relation to one another.

With respect to the electric current, the conclusion can be expressed as follows if it is assumed that the conductor conducts only through electrolysis: So long as the force acting on the conductor is below a certain limit it will produce no current whatever, but if it has reached this limit, then suddenly a very strong current will flow. But this conclusion is flatly contradicted by experience. Even the smallest force causes a current, conducted by alternate decompositions and reunions, and the intensity of this current increases in accordance with Ohm's law in proportion to the electromotive force.

It follows from these considerations that the above supposition to the effect that the part-molecules of an electrolyte are bound together in the fixed relation of whole molecules and that these have a definite and regular arrangement must be untrue.

* * * * * * *

I believe therefore that the following hypothesis by which this contradiction is removed, and which, as it seems to me, is in harmony with other known facts, deserves some consideration.

In my treatise "On the mode of motion, which we call heat," I have expressed the view that in liquids the molecules have no definite positions of equilibrium, about which they only oscillate, but that their motions are so lively that they thereby constantly come into entirely changed and new relations to one another and move among one another in an irregular way.

Let us now imagine in an electrolytic liquid a single part-molecule present, for example, an electro-positive one, the electrical condition of which we shall assume is exactly the same as at the moment when it was separated from a complete molecule. I believe now that while this part-molecule moves about among the whole molecules, under the many relations which it can assume, sometimes those will occur in which it will attract the negative part-molecule of an undissociated molecule with greater force than that with which the two parts belonging to an undissociated molecule, whose relation to each other is

not entirely unchangeable, attract each other at this same instant. As soon as this condition occurs it will soon join itself to this negative part-molecule and the positive part-molecule formerly bound to the same thereby becomes free. This one now in turn moves about free and after a time decomposes another whole molecule in the same manner, and so on. All these movements and decompositions occur in the same irregular manner as the heat motions by which they are set going.

* * * * * * *

When now in a liquid, whose molecules already find themselves in such motion that they exchange their part-molecules in an irregular way, an electric force acts which tries to drive all the positive part-molecules in one direction and the negative ones in the opposite, then it is easy to understand what differences in the mode of the molecular movements must ensue.

A free part-molecule will then no longer follow the irregularly changing directions which it is forced to pursue by the heat motions, but it will change the direction of its motion to correspond with the acting force; so that although the motions of the positive part-molecules are very irregular still a certain direction will prevail among them; and likewise the negative part-molecules will move under compulsion in the opposite direction.

* * * * * * *

If one considers within a liquid on which an electric force acts a small surface at right angles to the direction of the force, then through this area more positive part-molecules pass in unit time in the positive direction than in the negative, and more negative part-molecules in the negative than in the positive direction, * * * so that a certain excess number of positive part-molecules go in the positive direction and a certain excess number of negative part-molecules in the negative direction through the small area. The magnitude of these two numbers does not need to be the same, since it depends also, outside of the force urging them, which is the same for both, on the degree of their mobility, and this may for many reasons be different for different part-molecules.

These opposite movements of the two kinds of part-molecules compose the voltaic current within a liquid.

* * * * * * *

By this conception of the state of liquids the difficulty mentioned above vanishes. It is readily seen that the influence which the electric force exerts on the irregular molecular decompositions and motions already existing does not begin when the force has reached a certain value, but that even the smallest force must act on them, and that the amount of this action must increase with the magnitude of the force. The entire process then agrees well with Ohm's law.

* * * * * * *

If we compare the older Grotthus theory with the one here developed, the difference lies chiefly in this: In the former it was assumed that the motion is first brought about by the electric force and takes place in two definite directions only, while the decompositions go on regularly from molecule to molecule, but in the latter the motions already present are only modified, not to the extent of making them entirely regular, but only so that among the great multitude of motions those in the two definite directions prevail.

These ideas of Clausius are so fundamental in the modern theory of electrolysis that I have thought it best to translate them freely

rather than to paraphrase them. Clausius belongs to our own day. The gray hair and benign expression of this beautiful old man made a lasting impression on me as I saw him at the International Electrical Congress in Paris in 1881.

Grotthus conceived of the motion of the part-molecules as taking place under electric force only by the progressive exchange of partners in a polarized chain of molecules. Clausius rejected the fixed equilibrium in the normal condition of an electrolyte, and assumed some free part-molecules or, as Faraday named them, ions; and the dissociation imagined by Clausius may be described as temporary, or a continuous exchange of partners in chemical association. Williamson as early as 1851 declared "that in an aggregate of the molecules of every compound a constant interchange between the elements contained in them is taking place." This view Clausius rejected. The assumption that only a few of the molecules in a solution are dissociated into ions appeared to him to satisfy the facts of electrolysis.

The first attempt to answer the question as to the manner in which the facts of electrical conductivity are reconciled with those of general chemistry was contained in the theory of Grotthus; the second attempt was made by Clausius in 1857, and thirty years later a further answer was made in the work of Arrhenius.

Another question relates to the intimate relation between the passage of electricity through an electrolyte and the simultaneous motion of the ions, the ponderable attendant of the electrical transfer. The law of Faraday paved the way for an answer to this question; the reply of the present is largely the work of Hittorf and of Kohlrausch.

The simplest statement of Faraday's discovery in electrolysis is that the passage of a fixed quantity of electricity is always associated with the transfer of a gram equivalent of the ion. The passage through an electrolyte of 96,550 coulombs of electricity always releases or deposits a gram equivalent of an ion; that is, a gram molecule of an ion whose valence is one, or half a gram molecule of an ion whose valence is two. This law demonstrates that there is a fixed minimum, called by Helmholtz *the atomic charge*, conveyed by univalent ions, others conveying only integral multiples of this charge.

The researches of Hittorf on the migration of ions demonstrated that the observed change in concentration at the electrodes during electrolysis makes it necessary to assign to the positive and negative ions different velocities. Hittorf's work, though of fundamental importance, commanded but little attention at the time of its publication. In fact, it was opposed by the leaders of physical science and was not accepted till thirty years later.

Let me now recount several steps in the revision of electrolytic theory.

Grotthus supposed "that at the moment of the segregated appearance of the hydrogen and oxygen there takes place a division of their natural electricity, either by their contact or by mutual friction, so that the former assumes the positive, the latter the negative condition," and that the links of his chain exchanged partners in such a way as to leave only the end links free.

Clausius assumed "that the ions are not permanently united with each other; that part of them exist in the liquid in an uncombined state, wandering about seeking partners." The electric force imposes on all free ions a uniform drift. To Clausius, therefore, should be assigned the introduction of the theory of dissociation to explain electrolysis. But the dissociation of Clausius was only slight and was conceived to be the accompaniment of a shifting and unstable equilibrium.

Scientific judgment respecting the assumption of Clausius remained in abeyance for thirty years, when Arrhenius published his celebrated memoir on The Dissociation of Substances Dissolved in Water. An intermediate step, not originally devoted to the theory of dissociation, was Van't Hoff's paper on The Rôle of Osmotic Pressure in the Analogy between Solutions and Gases. The significant feature of this paper is the generalization of Avogadro's law to the effect that—

> The pressure which a gas exerts at a given temperature if a definite number of molecules is contained in a definite volume is equal to the osmotic pressure which is produced by *most substances* under the same conditions if they are dissolved in any given liquid.

The major part of Van't Hoff's paper deals with nonelectrolytes or organic compounds, such as a solution of sugar, which show little or no deviation from Avogadro's law as applied to osmotic pressure. When he alludes to those substances which exhibit abnormally large osmotic pressure, he acknowledges his indebtedness to the personal suggestion of Arrhenius to the effect that the solutions obeying the law of Avogadro are nonconductors of electricity, a fact indicating that they are not broken down into ions, while solutions which give higher values of the osmotic pressure than accord with the laws of gases are all electrolytes. But if these suffer partial dissociation in solution, then the number of particles is increased, each ion contributing to the pressure as much as a complete molecule. The excessive osmotic pressure is thus accounted for.

Arrhenius divided the molecules in a conducting solution into active and inactive portions. The former are those whose ions are independent of one another in their movements; the latter are the

remaining molecules whose ions are firmly bound to each other, and the ratio between the two he called "the activity coefficient."

The significant conclusions of Arrhenius are:

1. "That Van't Hoff's law holds not only for *most*, but for *all substances*, even for those which have hitherto been regarded as exceptions (electrolytes in aqueous solution)."

2. "That every electrolyte (in aqueous solution) consists partly of active (in electrical and chemical relation) and partly of inactive molecules, the latter passing into active molecules on increasing the dilution, so that in infinitely dilute solutions only active molecules exist."

The ratio of the active to the inactive molecules, or the activity coefficient, is intimately connected with the electrical conductivity of solutions. Molecules dissociated into ions are alone capable of conducting or conveying electricity through a solution. The inactive molecules are at best only inert and take no part in the electrical transport. The activity coefficient increases with the dilution—that is, the molecular conductivity, which expresses essentially the conductance of a given number of molecules in solution, is greatest when the dilution is such that all molecules of the solute are dissociated. This is the essential significance of the researches on electrolytic conductivity, so far as they bear on the theory of electrolysis.

The transition from the incidental and almost infinitesimal dissociation assumed by Clausius to the ideal infinite dilution and complete dissociation taught by the "Leipzig School" marks the essential revision of the theory of electrolysis made in recent years.

The theory of ionization has now passed beyond the bounds of electrolytic solutions. As Van't Hoff imported the gas law into solutions to explain osmotic pressure, so others, like J. J. Thomson, have seized on electric convection by ions to explain electrical discharges through gases. It is now conceded that the only tenable explanation of electric currents through gases is that of convection by ions. The ionization of gases is brought about by ultraviolet light, by Roentgen rays, and by the radiations from radio-active substances. The electric charge conveyed by ions in gases appears to be identical with the charge conveyed by ions in an electrolyte in aqueous solution, but the masses conveying negative charges are only about the one-thousandth part of the hydrogen ion.

The passage of electricity through a gas, as well as through an electrolyte, is accompanied by chemical changes; and chemical decomposition, says J. J. Thomson, is not to be considered an accidental attendant on the electrical discharge, but an essential feature without which it could not occur.

In reviewing the changes that have occurred in the theory of

electrolysis I would not be understood to imply that we now have the ultimate truth. Many cogent objections have been urged against the theory of dissociation in its present form. Theories should be regarded as helps or scaffolds only; they are necessary for the construction of the edifice of truth, and they finally disappear like the staging. We should use them as temporary expedients, not retaining them till the whole edifice is completed, but only until a grand arch is finished, some minaret or tower emerges against a clear sky or light streams through some noble window.

The physicist or chemist, who is more intent to ascertain the truth than to preserve consistency, holds to a theory no longer than he finds it able to furnish support. Faraday, the prince of research, said that experimental work is a great disturber of preconceived theories.

Just now the dissociation theory is in a state of siege, with many valiant defenders. The objection is urged that there are many cases of electrolytes in solution in which the osmotic pressure does not exceed that required by the gas law. Hence, there can be no dissociation. Also that the simplest cases of electrolysis are those of a molten salt, such as silver electrodes in molten silver chloride. In these cases there is no complication with a solvent and no dissociation by solution. In what way, then, is that migratory freedom of the electrically charged part-molecules, which is assumed in the theory of dissociation, secured in a molten salt? Doctor Kahlenberg has shown that "a normal solution of trichloracetic acid in allyl mustard oil is a poorer conductor of electricity than the purest water which Kohlrausch ever prepared in contact with air, and yet this solution attacks dry magnesium rapidly, and decomposes dry carbonates of sodium and potassium." But chemical reactions are assumed to depend on dissociation into ions, as does electrical conductivity.

This much is generally accepted: "The ions must be free to move; but this migratory freedom may be secured either by ionic interchanges between the molecules, as Clausius imagined, or by a prolonged separation in accordance with the dissociation hypothesis of Arrhenius and Planck. The essential point in the general ionic theory is the migratory freedom."

The solution of obscure problems, like those of electrolysis, in which event the chief agent itself is an elusive enigma, is necessarily one of prolonged effort, with many a flamboyant processional and the not infrequent refrain of the later recessional. But there is no occasion for discouragement, for we are destined to struggle forever with the unsolved problems of the here and the hereafter.

It is often darkest just before the dawn. Sometimes, too, we emerge into the light with a suddenness that blinds before the eye

adjusts itself to the new illumination. One dreary day in April I took the train in Switzerland over the St. Gotthard route. We entered the north end of the tunnel at Goeschenen with a clouded sky and snowflakes swirling through the air. Ten minutes passed in the darkness a thousand feet beneath the village of Andermatt—fifteen, seventeen, and then the train ran out on the Italian side of the great divide at Airola into a burst of sunshine and clear sky and white-capped Alpine peaks and tempered winds and the pale green of olive groves. So sudden was the transformation that an involuntary exclamation of surprise and delight ran through the train. The experiences of the last twenty years warn us that we must be prepared for similar surprises in the illumination that physical science is shedding on the world of nature. We need not prophesy; we need only work and wait.

RECENT PROGRESS IN ASTRONOMICAL RESEARCH.

By C. G. Abbot.

I.—ACTIVITY IN SOLAR INVESTIGATION.

Each periodic return of the time of maximum sun-spot occurrence brings with it a freshened interest and renewed activity in solar observations. This revival of solar research has been uncommonly marked of late, and promises a steady and fruitful continuation of work, even now that the sun-spot maximum has passed. Two important international conferences to consider solar research have been held, the first at St. Louis in 1904, the second at Oxford, England, in 1905, and an "International Union for Cooperation in Solar Research" has been formed. The success of this promising movement has been principally due to the efforts of Prof. George E. Hale and Prof. Arthur Schuster, who by extensive correspondence and personal intercourse with astronomers and physicists, and by obtaining the support of the International Association of Academies, secured a good attendance of men of ability at the two conferences just mentioned.

To understand the objects of the Union, it may be recalled that notwithstanding that the sun is the promoter of life on the earth, the controller of climate, and the only star which is near enough to admit of detailed study, yet observation of this, the most important celestial object, has hitherto been chiefly limited to eclipse observations, estimations of sun-spot numbers, appearance of the prominences, regulation of time, and occasional observations of peculiarities of spectrum, time of rotation, and distribution of brightness. The nature of sun-spots, the cause of their periodicity, their level as compared with the photosphere, the cause of their drift over the surface of the sun, the nature and thickness of the envelope which absorbs the solar rays, the exact wave lengths of the lines in the solar spectrum, the nature of the corona, the amount of the solar radiation available to the earth, the question whether solar radiation is constant or variable in amount, the connection between terrestrial magnetism and solar activity, the dependence of the earth's climate on the solar radiation, the temperature of the sun's surface, the ques-

tion as to the source of the heat of the sun—all these and doubtless other questions of equal interest are still in dispute.

The Union seeks to foster a spirit of interest in solar research; to suggest needful investigations; to avoid unnecessary duplication of work; to promote, where desirable, uniformity of methods of reduction of observations; and especially to encourage solar observations in regions of the earth where they have hitherto been neglected, so as to tend to keep the sun always under observation, that no unusual and interesting phenomena may escape being recorded. Besides these general activities the following special subjects were discussed and are receiving the attention of expert subcommittees appointed at the Oxford meeting.

1. Standards of wave length.—The first absolute measures of the wave length of light were made by Sir Isaac Newton about the year 1704, although he did not recognize light to be propagated by waves at all, and interpreted his results in accordance with the corpuscular theory. The first advance came with the invention of the diffraction grating by Fraunhofer in 1815, and his measurements of the wave lengths of the principal lines of the solar spectrum were the standards till 1868. In that year Ångström published the first map of the solar spectrum upon the normal or wave-length scale, basing the wave lengths upon his own determinations. In recognition of his great work, wave lengths have generally been stated since his time in the so-called "Ångström units," or ten millionths of a millimeter. Thus the wave lengths of the yellow lines of sodium are near 5,890 Ångström units.

Twenty years later a new era of spectroscopy was made possible by the work of Rowland. After inventing devices for correcting the errors in the cutting of screws, and other devices for correcting the errors which would be introduced in actual ruling by the errors left outstanding in the most perfectly corrected screw, he ruled diffraction gratings of an order of excellence and size till then unapproached and only very recently excelled. He invented also the concave grating, and showed how it might be used in the spectroscope without additional aid of lenses or mirrors to focus the rays.

There is a characteristic of the grating spectrum which was used by Rowland, Langley, and many others for connecting (as was supposed, rigidly) the wave lengths of different spectral rays. This consists in the fact that a large number of spectra are thrown by the grating in the same direction, so that if light of wave length 7,000 Ångström units was found in the spectrum of the first order at a certain point, there would be at the same point light of $\frac{7000}{2}$, $\frac{7000}{3}$, $\frac{7000}{4}$, * * * Ångström units in the higher orders of spectra.

Aided by this relation and employing the new and unexcelled concave gratings, together with photographic plates of the finest grain

which he made for the purpose. Rowland photographed the spectrum of the sun and that of numerous metals as produced in the electric arc, giving the wave lengths generally to thousandths of an Ångström unit or to seven places of figures. The publication of these results, including thousands of spectrum lines hitherto unrecorded, together with very numerous statements of the coincidences of solar and metallic lines, was thought at the time to be the last word on the subject of standard wave lengths which would be needed for many years. Rowland, however, did not determine the absolute scale of his system of wave lengths, but based it on the measures of the wave length of the D lines made by Bell and others, and himself observing by the method of coincidences, as above explained, stood sponsor only for the relative accuracy of the measures throughout the spectrum.

In 1893 Michelson and Benoit, by the aid of the Michelson interferometer, which, though based finally on the same principles as the grating, is yet wholly different in its make-up and use, determined the absolute wave length of the red ray of cadmium in terms of the standard meter. These results proved that Bell's value of the wave length of D, adopted as the basis of Rowland's system, was too large by about two-tenths of an Ångström unit. A little later it was shown by Jewell that there is a lack of exact coincidence between solar and metallic spectrum lines, and about the same time it was shown by Humphreys and Mohler that pressure played a part in determining the apparent place of lines. About 1900 Kayser discovered that Rowland's tables were not exactly consistent in themselves, for it made a difference, whether the observer measured to one or another of Rowland's lines, what wave length he would assign to some line intermediate between them.

About this time Michelson proved mathematically that certain errors in the ruling of gratings are possible, which destroy the exact validity of the method of coincidences, so that a line of given wave length in the first order spectrum does not necessarily absolutely coincide with one of half that wave length in the second-order spectrum. Kayser immediately tested this conclusion practically with two large Rowland gratings in his possession, and found differences of as much as 0.03 Ångström units traceable to this cause.

Thus in the course of fifteen years after the publication of Rowland's spectrum maps it was found that the absolute scale of wave lengths he had adopted was in error by 0.2 Ångström unit and, what is far more serious, there exists a source of error unsuspected till recently, which has introduced inconsistencies of several hundredths of an Ångström unit in the relative accuracy of Rowland's tables.

These conclusions are independently verified by comparison of Rowland's numbers with the apparently highly accurate determina-

tions of wave length of numerous lines made by Messrs. Pérot and Fabry with their special interferometer.

To the general reader it might seem a matter of indifference that defects amounting to only one part in 250,000 should exist in the relative accuracy of the wave lengths of different solar and metallic spectrum lines, but important conclusions in at least three different lines of research depend on these small differences. First may be mentioned the determination of the motions of heavenly bodies in the line of sight of the observer, which depend on the measurement of the shifting of the lines of their spectra. In this work an error of 0.02 Ångström unit in the wave lengths corresponds to a difference of velocity of more than a mile a second. As another research demanding accurate standards of wave length may be mentioned the comparison of metallic and solar or other celestial spectra, for the purpose of determining the constitution of the heavenly bodies. It has often occurred heretofore that erroneous theories of the broadest scope have been based on a supposed coincidence of spectral lines, which truly were of very slightly differing wave length. Thirdly, the investigations of regularities in the distribution of the different spectral lines of an element, on which may rest important theories of the inner constitution of matter, would be vitiated by errors of the wave lengths such as have been noted.

It has been decided by the Union that a new system of wave lengths is necessary; that it shall be based on the wave length of a suitable spectrum line, to be fixed permanently, in units differing as little as possible from $\frac{1}{10000000}$ millimeter, and to be called Ångström units; that secondary standards shall be determined by an interferometer method at distances not greater than 50 Ångström units apart, and the source of light for the determination shall be produced in the electric arc of 6 to 10 amperes; that tertiary standards shall be selected at distances of 5 to 10 Ångström units whose wave lengths shall be determined from the secondary standards by the aid of gratings. This work was placed in charge of a committee of expert spectroscopists, and progress is reported from several laboratories in making the measurements required.

2. *Solar radiation.*—The amount of solar radiation may be expressed in terms of the rise of temperature in degrees centigrade which a solar beam of a square centimeter cross section, shining for a second of time, will produce if entirely absorbed and transformed into heat within a mass of one gram of water at maximum density. Such units of measurement are called calories (or therms) per second. Inasmuch as the amounts usually measured of solar radiation are small, it is customary for the sake of convenience to use as a unit of solar radiation a calory per minute, for the quantity usually observed is between 1 and 2 calories per minute.

Measurements of solar radiation have been made by J. Herschel, Pouillet, Forbes, Violle, Langley, Crova, K. Ångström, and others, in various situations as regards altitude and sky conditions, and these investigators and others have devised and used many kinds of apparatus for the purpose. Such instruments are known as pyrheliometers or actinometers, and the best known of them are Pouillet's water pyrheliometer, Violle's actinometer, Crova's alcohol actinometer, and Ångström's compensation pyrheliometer. Of these four instruments, all excepting Crova's purports to be capable of giving absolute measurements when the constants depending on form and dimensions of the particular instrument are determined. As a matter of fact, however, differences and theoretical objections are still found, so that the absolute amount of solar radiation, as determined and published by different observers, is doubtful to the extent of 10 per cent, at least. Futhermore, there is no common ground of comparison, so that the amount of radiation found by one observer at one locality can not be compared with that found by another observer in quite another part of the world.

The Union ventured to attempt to alter this state of affairs by resolving to adopt the readings of the Ångström compensation pyrheliometer as standard, notwithstanding that it is known that this instrument necessarily reads too low and possibly by amounts varying with the locality. Still, as this type of instrument is somewhat generally distributed in the world, it seems possible that some abatement of the confusion of radiation measurements may be brought about by this action of the Union. Recognizing the need of a more certain standard, a committee was appointed to investigate this subject.

Measurements of solar radiation at the earth's surface do not suffice to indicate the amount of radiation available to the earth, or whether this amount varies sufficiently to affect climates. For the atmosphere of the earth scatters, reflects, and absorbs the sun's rays, in ways which are intricate and difficult to determine, and the amount of hindrance to radiation which the atmosphere offers varies so rapidly and differs so widely from place to place and from day to day that nothing can be concluded as to the possible variability of the sun from simple measurements of solar radiation at the earth's surface.

As stated in former Smithsonian reports, the Astrophysical Observatory of the Smithsonian Institution has been investigating the amount of solar radiation at the earth's surface and the amount absorbed in the atmosphere, for several years, by methods involving not only measurements of the total radiation, but also measurements of the intensity of each ray of the spectrum by itself. The probability that the solar radiation outside the earth's atmosphere actually

varies often by amounts of 5 or 10 per cent, and that these variations affect temperature all over the earth, seems to be confirmed by these measurements.

Resolutions were adopted by the Union advising the trial of several kinds of investigation tending to confirm or disprove the supposed variability of the sun, and a committee was charged with reporting the best methods of procedure in observation and reduction of measurements.

Partly in response to the recommendations of the Union, and partly owing to the interest displayed in the subject by some of the foremost astronomers and physicists of the time, new observatories have recently been organized, chiefly for solar work, and older observatories are beginning new series of observations in this field. Most notable, of course, is the Carnegie Solar Observatory on Mount Wilson, in California, where daily photographs, both direct and with the spectroheliograph, are being made, and where the determination of the time of rotation of the sun, the spectrum of sun spots and its relations to the spectra of stars and terrestrial sources, besides other interesting studies, are already being actively pushed. Solar work of several important kinds has recently been begun, or is about to be taken up, at a number of observatories in India and Australia, some of which are supported by government. Our own Government has for about fifteen years supported the Astrophysical Observatory of the Smithsonian Institution, which has always been a solar observatory, and now solar photographs are made regularly at the United States Naval Observatory. It is also definitely intended to undertake solar observations at the new Mount Weather station of the United States Weather Bureau.

In England and in Italy long series of records of solar phenomena have been made by Government and other observers; and the counts and drawings of sun spots have rewarded by substantial results the patient persevering study, through years and decades, of many noted European observers, both amateur and professional, including Schwabe, Carrington, Wolf, Wolfer, Howlett, Sidgreaves, and others.

When so much of interest remains clearly waiting to be discovered, and so many observers furnished with the powerful appliances of modern astronomy and physics are enthusiastically entering the field, it can not be doubted that the next few years will mark an epoch in solar research.

II.—VARIATION OF LATITUDE AND THE WANDERING OF THE POLE.

In the Smithsonian reports for 1893 and 1894 appeared two articles by Sir Robert Ball and Prof. J. K. Rees, respectively, in which the then newly proved variation of latitude is described. While in actual magnitude small, this wandering of the pole of the earth is so

MOUNT WILSON OBSERVATORY.

Mount Wilson Observatory Telescope House.

far from being insignificant that a number of observatories have been founded by international cooperation whose principal function is the accurate study of this phenomenon. These international latitude observatories have been in full operation for six years, and interesting results of their work are now published.

While the possibility of latitude variation was recognized from the careful work of European observers as early as 1885, the actual discovery of the variation and of the laws which govern it are the work of an American astronomer, Mr. S. C. Chandler, carried through in the face of the opposition of long-accepted theory and of the opinions of astronomers in general. It will be interesting to recall briefly some of the steps and conclusions involved in this remarkable discovery.

The phenomenon in question has, of course, no connection with precession or nutation, but is concerned only with a variation of the position of the axis of rotation of the earth within the earth itself. Its effect is to periodically increase the latitude of places on one side of the earth and simultaneously diminish that of those on the opposite side of the earth by amounts of the order of 30 or 40 feet. In other words, the pole is 30 or 40 feet nearer Washington, and the same farther from Peking at one time than another.

Mr. Chandler's first announcement of his discovery in 1891 began as follows:

In the determination of the latitude of Cambridge (Mass.) with the Almucantar about six years and a half ago, it was shown that the observed values, arranged according to nights of observation, exhibited a decided and curious progression throughout the series, the earlier values being small, the later ones large, and the range from November, 1884, to April, 1885, being about four-tenths of a second. There is no known or imaginable instrumental or personal cause for this phenomenon, yet the only alternative seemed to be an inference that the latitude had actually changed. This seemed at the time too bold an inference to place upon record, and I therefore left the results to speak for themselves. * * *

He gives further data of his own on the subject tending to support the hypothesis of a change of latitude, and then refers to European observations contemporaneous with his own as follows:

Curiously enough Doctor Küstner, in his determination of the latitude from a series of observations coincident in time with those of the Almucantar, came upon similar anomalies, and his results, published in 1888, furnish a counterpart to those I had pointed out in 1885. The verification afforded by the recent parallel determinations at Berlin, Prague, Potsdam, and Pulkowa, which show a most surprising and satisfactory accordance as to the character of the change in range and periodicity with the Almucantar results, has led me to make further investigations on the subject. * * *

Mr. Chandler then proceeded to give detailed results of the investigations, which he summed up as follows:

The general result of a preliminary discussion is to show a revolution of the earth's pole in a period of 427 days, from west to east, with a radius of 30

feet, measured at the earth's surface. Assuming provisionally, for the purpose of statement, that this is a motion of the north pole of the principal axis of inertia about that of the axis of rotation, the direction of the former from the latter lay toward the Greenwich meridian about the beginning of the year 1890. This, with the period of 427 days, will serve to fix approximately the relative positions of these axes at any other time for any given meridian. It is not possible at this stage of the investigation to be more precise, as there are facts which appear to show that the rotation is not a perfectly uniform one, but is subject to secular change, and perhaps irregularities, within brief spaces of time.

These results of observation fell squarely across the long-accepted theory of Euler, according to which the variation of latitude, if any, must be a uniform one of ten months, and also contradicted the result of careful reduction of excellent observations from which it had been concluded that no sensible wandering of the pole did in fact take place. The theoretical difficulty was, indeed, soon partly removed by Professor Newcomb, who pointed out that the fluidity of the ocean and the elasticity of the earth had been neglected in deriving ten months as the theoretical period of a possible rotation of the earth's pole, but at the same time he professed himself unable to account on the principles of dynamics for a variation of the period of the inequality, unattended by an alteration of its amplitude during the preceding half century, conclusions which had come from recomputations which Mr. Chandler had in the meantime made of the classic observations of Bradley in 1728 and others of different periods of the nineteenth century

Under the spur of the theoretical difficulties stated by Professor Newcomb, Mr. Chandler collected an immense mass of evidence on the subject, involving the reduction of more than thirty-three thousand observations made by nine different methods, comprising the work of seventeen observatories, distributed over both the northern and southern hemispheres, and covering the interval of time from 1728 to 1890. From this great array of evidence the fact of the wandering of the pole was not only clearly confirmed, but also the variation of its period and amplitude came out without question, and an insight was gained as to the causes of this baffling phenomenon as follows:

The observed variation of the latitude is the resultant curve arising from two periodic fluctuations superposed upon each other. The first of these, and in general the more considerable, has a period of about 427 days, and a semiamplitude of about 0.12 second. The second has an annual period with a range variable between 0.04 and 0.20 seconds during the last half century. During the middle portion of this interval, roughly characterized as betw een1860 and 1880, the value represented by the lower limit has prevailed, but before and after these dates, the higher one. * * *

As the resultant of these two motions, the effective variation of latitude is subject to a systematic alternation in a cycle of seven years' duration, resulting from the commensurability of the two terms. According as they conspire or

interfere, the total range varies between two-thirds of a second, as a maximum, to but a few hundredths of a second, generally speaking, as a minimum.

In consequence of the variability of the coefficient of the annual term above mentioned, the apparent average period between 1840 and 1855 approximated to 380 or 390 days; widely fluctuated from 1855 to 1865; from 1865 to 1885 was very nearly 427 days with minor fluctuations; afterwards increased to near 440 days. * * *

Mr. Chandler expressed these results mathematically by an equation in which the variation of latitude is given as the sum of two periodic terms, and he found that this expression very closely represented all the observations he had so laboriously collected.

The valuable consequences of this discovery of Mr. Chandler's are numerous. First of all, they showed why certain series of observations made with the most painstaking care at the national observatories of the United States, Great Britain, and Russia had exhibited discordancies which had led to distrust of the very best pieces of apparatus, and had involved laborious, costly, and fruitless efforts to remove what now were found to be nonexisting defects. In some instances even the reputation for accuracy of able astronomers had been clouded by such inexplicable discordancies in their work, which, in the light of the new discovery, now prove only the evidences of the faithfulness and accuracy of these observers. Again, as to the constant of aberration, on which depends one important method of determining the distance of the sun (that great astronomical quantity on which all the conclusions as to the distances, masses, and other elements of the solar system hang, together with all the exact predictions depending on solar theory), it proves that the determinations of this important constant are sensibly affected by the variations of latitude.

Professor Turner, in his Astronomical Discovery, has the following passage indicating still another possible effect of the wandering of the pole:

If the axis of the earth is executing small oscillations of this kind, there should be an effect upon the tides; the liquid ocean should feel the wobble of the earth's axis in some way; and an examination of the tidal registers showed that there was, in fact, a distinct effect. It may cause some amusement when I say that the rise and fall are only a few inches in any case, but they are unmistakable evidences that the earth is not spinning smoothly, but has this kind of unbalanced vibration, which I have compared to the vibrations felt by passengers on an imperfectly engineered twin-screw steamer. A more sensational effect is that apparently earthquakes are more numerous at the time when the vibration is greatest. We remarked that the vibration waxes and wanes, much as that of the steamer waxes and wanes if the twin screws are not running quite together. Now, the passenger on the steamer would be prepared to find that breakages would be more numerous during the times of vigorous oscillation, and it seems probable that in a similar way the little cracks of the earth's skin, which we call great earthquakes, are more numerous when these unbalanced vibrations are at their maximum; that is to say, about once every

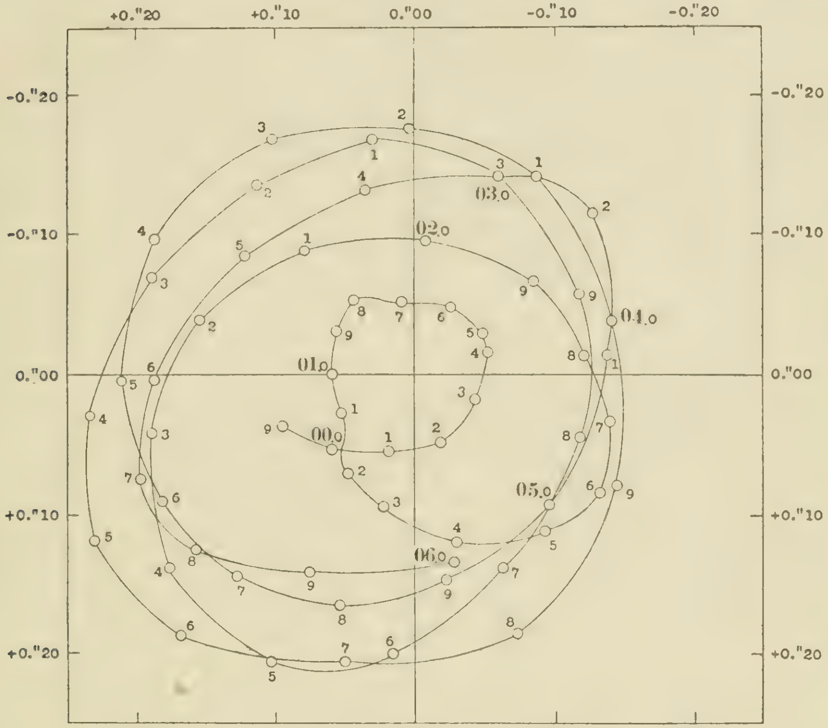
seven years. This result is scarcely yet worthy our complete confidence, for our observations of earthquakes have only very recently been reduced to proper order; but if it should turn out to be true, it is scarcely necessary to add any words of mine to demonstrate the importance of this rather unexpected result of latitude variation.

By the beginning of the year 1893 the fact of a variation of latitude was generally admitted, and it was held to be of such importance for the accurate work of geodesy that a long series of exact determinations of the variation seemed to be highly desirable. Accordingly, at the meeting of the International Geodetic Association in 1895, it was proposed by Doctor Foerster, of Berlin, that the work should be continued under the auspices of the association. A special fund was raised to defray the expense of the undertaking, and four stations, all within 12 seconds of the same latitude (about 38° 8′ N.) were chosen, namely, Carloforte, in the island on San Pietro; Mizusawa, in Japan; Ukiah, in California, and Gaithersburg, in Maryland. To these were soon added Tschardjui, in Siberia, a station supported by the Russian Government, and the observatory at Cincinnati, which offered to join in the work. The first four stations are wholly supported by the International Geodetic Association, excepting that the observer at Gaithersburg is an officer of the U. S. Coast Survey. Very lately the International Geodetic Association has added two stations in the southern hemisphere (at latitude 31° 33′ S.), namely, Bayswater, in Western Australia, and d'Oncatwo, in the Argentine Republic. The expense of maintaining the four first mentioned stations and of reducing and publishing the results of observation has been about $14,000 yearly.

The results obtained are of a very high degree of accuracy, so accurate indeed that a new type of annual variation, having only 0.04″ amplitude, has been discovered by the Japanese, Mr. Kimura, in charge of the work at Mizusawa. This interesting new variation is independent of the longitude of the observing station and produces the same effect as would a movement of the center of gravity of the earth to and fro along its axis by an amount of about 6 feet per year.

The existence of the two principal factors in the variation of latitude, substantially as discovered by Mr. Chandler, are fully confirmed by the observations of the international latitude stations which have now been continued for six years. The period of the principal one is at present thought to be 437 days, however. The accompanying figure shows in a graphical form exactly how the earth's axis has been wobbling within the earth in these last six years. It is taken from a recent paper on the subject by Prof. Th. Albrecht, who, with Dr. B. Wanach, has reduced and published the international observations. In the figure the scale of motion is indicated in seconds

of arc, which can be translated into feet or meters by remembering that one second of arc at the pole is about 100 feet, or 30 meters, so that the diameter of the larger curves is about 40 feet, or 12 meters. The time is indicated in years and tenths of a year by the figures adjoining the curves themselves. Thus, beginning with 1899.9 the curve passes over the years 1900, 1901, etc., and ends at 1906.0. It is plainly shown by this irregular curve what an apparently lawless



Movement of earth's axis, 1899 to 1906.

wobble of the earth's axis is produced by the joint action of two periodic factors, one of about 437 days and one annual, the first of constant and the second of variable amplitude. Since 1890 it has been found that five of the long periods are almost exactly equal to six of the shorter, so that the whole movement nearly repeats itself every six years. It is interesting, though not conclusive, to note that the severe earthquakes of 1906 occurred soon after the time of maximum activity of the pole, which accords with the hypothesis touched upon by Professor Turner, as already cited.

ASTRONOMY ON MONT BLANC.[a]

By H. Radau.

Quo non ascendam? This is the intrepid device which the dean of French astronomers appears to have adopted, when, undeterred by dangers and fatigue, he persevered in founding an observatory, in the midst of the eternal snow, upon the highest summit of the European continent. Professor Janssen was well fitted for this enterprise by his previous mountain experiences—in the studies which he made in 1864 at the summit of the Faulhorn to determine the terrestrial absorption lines in the solar spectrum; in the researches carried out on Mount Etna in 1867 to test for the existence of water vapor in the atmosphere of Mars; in the expedition of 1868, when he passed a winter in the Himalayas, occupied with the spectroscopic study of the sun and stars, and in that of 1871 to the Nilgherries, when he convinced himself of the existence of the coronal atmosphere of the sun. Besides these expeditions, there was his visit in 1867 to the observatory at the Pic du Midi and, finally, his successive ascensions of Mont Blanc to resolve the question of the presence of oxygen in the sun. It was indeed these latter ascensions which led to the establishment of the astronomical observatory on the summit of Mont Blanc.

I.

It is worth while to state briefly why the astronomers of our day have chosen to establish their instruments at high altitudes. When one has passed some time under an overcast sky, which obscures the light and renders all observations impossible, he recognizes the advantage of a station above the clouds. But even when the sky is perfectly cloudless the atmosphere is still a serious obstacle, for it is in fact a translucent and changeable veil between the observer and the heavens. This veil is very thick at sea level, and both distorts and changes the nature of the images of celestial objects. First of all, by its refraction it falsifies the position of the stars more and more as they approach the horizon, because the denser layers of the

[a] Translated, by permission, from Revue des Deux Mondes, Paris, February 15, 1907, pp. 876–892.

air form there a larger proportion of the path of the beam of light. Another inconvenience, more serious from the point of view of physical astronomy, is the diffuse reflection of the atmosphere, which causes a beam of light to illuminate in all directions the air it traverses. The light of the sky is a great obstacle to investigations of objects near the sun, and for a long time it prevented the observation of the solar prominences excepting at the rare occasions of total solar eclipses. It is now possible to view them in full daylight, thanks to Janssen's discovery of a method of enfeebling the diffuse sky light by the aid of the spectroscope, while leaving nearly unchanged the monochromatic light of the prominences.

Among the effects due to the presence of the atmosphere should be mentioned the absorption which it exercises upon the radiations of the sun and stars, for by retaining a portion of such radiation it profoundly alters the quality of the rays which reach the earth's surface. Not only is the intensity of the rays reduced by the passage through the atmosphere, but their composition is essentially changed. This is the reason why the sun appears red near the horizon, and it is also the cause of some of the dark lines in the solar spectrum, lines whose terrestrial origin is attested by their variation at high and low sun. The effects we have been considering are much diminished when the observer stations himself at an altitude of several thousand meters.

At the summit of Mont Blanc (about 4,810 meters above the level of the sea) the barometer stands at 425 millimeters, from which it follows that the weight of the atmosphere above is still a little more than half that of the entire atmosphere. Upon the highest peaks of the Himalayas (8,800 meters) the barometric pressure is only about a third of its value at sea level, where each square meter of the earth's surface supports a weight of 10,000 kilograms of air. By choosing a station at a great elevation the difficulties which embarrass the observations of physicists and astronomers due to the presence of the atmosphere may be partly overcome. The measure of success which has already crowned tentative efforts in this direction has encouraged many who were hesitating to make the sacrifices accompanying perilous and costly ascents, and now we see mountain observatories multiplying and equipped with the most powerful instruments.

The most celebrated of these establishments is the magnificent Lick Observatory, on the summit of Mount Hamilton in California, in an admirable site at 1,300 meters above sea level. According to the report of its first director, E. S. Holden, the nights are continually fine during six or seven months of the year, and about half the time remaining may be employed for observing. This observatory was

constructed by aid of a legacy of $700,000, offered in 1874 by a rich merchant of San Francisco, James Lick, who made this gift to astronomy after being dissuaded from constructing a pyramid to serve for his tomb. Though the sum was so large, yet it would not have sufficed if the local authorities had not aided the project. A piece of ground more than 1,500 acres in extent was put at the disposal of the observatory; the county of Santa Clara appropriated $80,000 for the construction of a road 50 kilometers long from San Jose to the summit of the mountain, and finally the University of California promised an annual grant of $20,000. Thanks to these liberalities, the Lick Observatory was finished in 1888 and provided with good instruments, among them the great telescope of 36 inches diameter, and has ever since carried on such observations as have given it a very high reputation among astronomers.

The advantage of a high station had long been recognized when, in 1904, George E. Hale, formerly director of the Yerkes Observatory, founded a solar observatory on Mount Wilson, at an altitude of 1,800 meters. Preliminary experiments had demonstrated that the purity of the sky in this part of California left nothing to be desired, and the Carnegie Institution of Washington immediately came to the financial support of the new observatory, and has already appropriated for it the sum of more than $500,000. This is now the best equipped of all the solar observatories.

The station at Arequipa, Peru, a branch of the celebrated Harvard College observatory, was established in 1890 and is about 3 kilometers from the city, at an altitude of 2,457 meters. Not far distant is the high mountain, El Misti, on which a station for meteorological and other purposes was maintained for some time in connection with the Arequipa observatory. At Flagstaff, Ariz., at an altitude of 2,210 meters, is located the private observatory of Percival Lowell. The purity, dryness, and calm of the air there promote the brilliancy and steadiness of the telescope images. Besides these, there are in America many other high stations favorable to astronomical observations, but these are principally employed as meteorological stations and only occasionally for temporary astronomical expeditions, notably during eclipses. Of these may be mentioned Pike's Peak, Colo., having an altitude of 4,300 meters where Langley observed the eclipse of 1878; Mount Washington (1,938 meters), Mount Mitchell (2,040 meters), Mount Whitney (4,460 meters), and others.

It is easy to see that meteorology derives great advantage from the occupancy of high observing stations. There are to-day many of these in the Alps, the Caucasus, and the Himalayas, with altitudes of from 2,000 to 2,500 meters. In France the "Bureau Central Météorologique" directs the following high stations: Servance (1,216

meters), Briancon (1,298 meters), Puy de Dome (1,467 meters), Mont Aigoual (1,554 meters), Mont Ventoux (1,900 meters), Mont Mounier (2,740 meters), Pic du Midi (2,859 meters). The station on Mont Mounier is also utilized for astronomical purposes. It is believed by Messrs. Baillaud and H. Bourget that the Pic du Midi, where indeed there are some instruments, may become an excellent station for the astronomers. There should be added to this list the observatory which J. Vallot has constructed on Mont Blanc, upon the Bosses du Dromadaire, at an altitude of 4,350 meters. Established in 1890, moved and enlarged in 1898, it has rendered valuable service, which the Académie des Sciences in 1897 recognized by the award of the grand prize in physical science. The results of the work of Vallot and his assistants have been published by him in the Annales de l'Observatoire météorologique, physique et glaciaire du Mont Blanc, which form six quarto volumes. But the present paper is devoted to the subject of astronomy and it is time to return to M. Janssen.

In his first ascent of Mont Blanc, in October, 1888, he did not proceed beyond the inn at Grands Mulets, at the altitude of 3,000 meters, situated on the rocks at the junction of the Bossons and Tacconaz glaciers. At this time of the year the inn was already abandoned, and there had recently been a heavy fall of snow which had effaced the trail, hidden the crevasses, and rendered the ascent very difficult. Owing to these obstacles thirteen hours were consumed in reaching the chalet of Grands Mulets by a route which in the favorable season is traversed in four hours, and the travelers arrived greatly exhausted. Accordingly, when two years later Janssen determined to try to reach the summit he discarded all thought of ascending on foot and devised a sledge somewhat similar to those of Lapland. The guides were ill pleased with this innovation; but at length, on August 17, 1890, at 7 o'clock in the morning, Janssen left Chamonix in company with Durier and 22 guides and porters, reaching the chalet of Pierre Pointue about 10 o'clock and the inn at Grands Mulets at half past 5. On the next morning at 5 o'clock they left Grands Mulets, 12 guides dragging the sledge and carefully safeguarding against accidents, they reached about an hour after noon the station at des Bosses which Vallot had constructed. Here it was proposed to pass the night and resume the ascent the next morning, but in the night the weather changed suddenly, and a terrible storm burst upon them. It was the forerunner of the cyclone of August 19. They were obliged to wait three days, and Janssen had opportunity to reflect upon the advantage of a meteorological observatory well equipped with long-running self-registering apparatus in this high region, where the atmosphere disturbances are found in all their

savage violence. Finally, on the 22d, the weather moderating, Janssen continued the ascent with the 12 men still remaining under the orders of their chief, Frédéric Payot, for the others had demanded permission to return. Thanks to the indomitable energy of this faithful troop, the sledge was finally hauled to the summit, and after some hours given to rapid observing in excellent weather conditions they resolved to go down. At 2 o'clock they regained des Bosses, by night reached Grands Mulets, and on the next day traveled to Chamonix, where they arrived at 7 o'clock in the evening.

Professor Janssen has charmingly recounted the story of these and other ascents made in following years before the academy, and in a series of papers which appeared in the successive volumes of l'Annuaire du Bureau des Longitudes, so that it is not needful to refer to them here. These expeditions were preparatory, as we have seen, to the establishment of an observatory, and they furnished at the same time occasion for numerous valuable observations relating principally to the solar spectrum and the structure of the sun. One of the questions which interested Janssen was that of the existence of oxygen in the solar atmosphere, a question whose interest is connected with the important part played by this element in geological, chemical, and biological phenomena. Some spectroscopists, too prematurely, had maintained the existence of oxygen in the sun, but this conclusion was strongly disputed. The experiments of Janssen and of Egoroff had shown that the action of oxygen on light is shown by the presence of certain series of fine lines in the spectrum, known as A and B, and in addition to these there are faint bands which are found when the absorption is very strong. These fainter bands disappear from the solar spectrum when the sun is at all high in the heavens, and it is therefore natural to attribute them to the action of the earth's atmosphere. The fine oxygen lines, however, persist even when the sun is in the zenith, so that their origin is less certain.

One course of experiments would be to produce these lines artificially in the spectrum of the electric arc by interposing in the beam an absorbing layer equal to our atmosphere, and Janssen performed such an experiment in 1889 by observing at Meudon the spectrum of the electric light installed at the top of the Eiffel tower. The distance is about 7,700 meters and the rays traverse a layer of uniform density containing about the same amount of oxygen as the layer of variable density traversed by the beam of a star in the zenith. In the spectrum thus obtained the fine lines were found in their normal intensity, which is evidence of their terrestrial origin. A greater distance would be required to produce the fainter bands above mentioned.

Another proof of the terrestrial origin of the A and B groups of the solar spectrum would be furnished by their gradual decrease of intensity during a balloon ascension, or the ascension of Mont Blanc. This was the principal object of the first expedition of Janssen, and he was, in fact, able to note, with the aid of the spectroscope which he carried, an unmistakable diminution of the intensity of the B group owing to the great elevation of the station, but the height of Mont Blanc was insufficient to extinguish all the oxygen lines. M. le Comte de la Baume-Pluvinel has confirmed this result by photographing the B group of the solar spectrum at Chamonix, and on the summit of Mont Blanc in September, 1898. But the persistence of the lines is readily explained, for the laboratory experiments of Janssen have shown that a column of oxygen 120 meters long at atmosphere pressure is sufficient to produce an absorption giving rise to the B lines, while the atmospheric layer above Mont Blanc is equivalent to such a column of oxygen 900 meters long, or seven times as long as is required to produce the lines.

In order to eliminate the B group of lines it would be necessary to ascend to a height of 18 or 20 kilometers. Balloons provided with automatic recording spectroscopes will perhaps in time solve the problem. It should not be forgotten that the study of the oxygen bands is complicated by the presence among them of absorption lines of water vapor. Perhaps, also, the persistent visibility of the lines is partly due to the greater intensity of the light itself, owing to the decrease of the general absorption of the air at high altitudes.

Despite the difficulties which remain and which always attach to new researches, the concordance of the indications furnished by the several kinds of evidence which are available permits us to believe that the oxygen lines found in the solar spectrum have their source in our own atmosphere and that oxygen does not exist in the sun. This does not prevent us from admitting the possibility that the sun contains the matter going to make up oxygen, but perhaps in a state of dissociation.

II.

For carrying on researches of considerable magnitude it is not practicable to depend on simple ascents, even frequently repeated; and it is indispensable to provide a permanent observatory equipped with a number of instruments and suitable for a stay of considerable length. M. Janssen represented this need strongly to the Académie des Sciences in his report of the expedition of 1890, and his appeal was not neglected. M. Bischoffsheim, whose lamented death occurred some months ago, immediately offered 150,000 francs; Prince Roland Bonaparte subscribed 100,000 francs; Baron Alphonse de Rothschild,

20,000 francs; M. Janssen was put down for 10,000 francs as promotor. Thus from the first the new observatory could be considered as assured. Soon afterwards the promoters of the enterprise were constituted a society, which comprised Messrs. Léon Say, honorary president; Janssen, president; Bischoffsheim, secretary; Ed. Delessert, treasurer; Prince Roland Bonaparte, Baron A. de Rothschild, Comte Greffulhe, members. Léon Say, who interested himself in the matter deeply, made strong efforts to secure an annual subvention from the State.

The preliminary studies relative to the establishment of the observatory were commenced in August, 1891. They consisted first of all in the measurement of the thickness of the sheet of ice which covers the summit of Mont Blanc. M. Eiffel had promised to have these soundings made at his own expense and put them in charge of a Swiss engineer, M. Imfeld.

The summit of Mont Blanc is formed by a very narrow arête of rock, more than 100 meters long, running east and west. This arête terminates probably in peaks and has been imbedded in snow which has formed a crust thicker on the north side than the south, where it is more exposed to melting. Two horizontal galleries, each 23 meters long, were constructed about 12 meters below the crest without encountering rock, but only hard snow. It is therefore probable that the icy crust which covers Mont Blanc is more than 12 meters thick, and M. Janssen soon proposed a solution of the problem of construction in these novel conditions, which consisted in the laying of the foundations upon the permanent snowcap which forms the summit. All accounts of ascensions during the last century prove that the appearance of the smaller rocks near the summit has not changed much, and it may be concluded that the configuration of the top is being altered very slowly, if at all. It follows that a rigid construction securely anchored in position would be perfectly safe and relatively stable; but the question had to be settled whether the snow layer upon the summit offered sufficient resistance to support the weight of the structure. M. Janssen thought it necessary to make direct experiments to determine this.

During the winter there was erected near the Observatory of Meudon a hillock of snow as high as a single story. The snow had been rammed down as it was shoveled in, until it had acquired about the density of the snow in Mont Blanc. Upon the well-leveled summit was placed a pile of 30-kilogram lead weights. When 12 disks, of a total weight of 360 kilograms, had been piled up and afterwards removed, it was found that the depression had been only 7 or 8 millimeters. The result surpassed expectation, for the pressure upon the snow had exceeded 4,000 kilograms per square meter. An edifice

measuring 10 by 5 meters at the base might then weigh 200,000 kilograms without being likely to sink in the snow more than a few centimeters. If built on a rigid subbase and provided with jack-screws, any strains which might arise by settling could be relieved, and the whole could be leveled as it might require. In order to guard against the fury of the storms it seemed desirable to make the structure in the shape of a truncated pyramid and to bury the lower part in the snow, so as to have a large and strong foundation.

The object being approved by M. Vaudremer, the eminent architect, member of l'Académie des Beaux-Arts, the construction was commenced according to plans prepared under his direction. It comprised two stories, with a terrace and balcony. At the base the pyramid measured 10 by 5 meters. The underground parts which form the lower story are lighted by wide but low windows above the snow. A spiral stairway communicates between the two stories and the terrace, and extends above the latter to support a platform some meters above, designed for meteorological observations. Double walls protect the observers within from the cold, and the underground part has a double floor separating it from the snow. The structure, entirely of wood covered by canvas, was set up at Meudon and then taken apart and transported to Chamonix. The total weight of the materials exceeded 15 tons and made 700 or 800 loads for the porters. As a precaution the route was divided into four sections, with stopping places at the Grands Mulets (3,000 meters) and at Grand Rocher Rouge (4,500 meters). The first section, which comprised the route from Chamonix to the foot of the glacier, allowed of the use of the animals. In the second stage, ending at the public inn on the Grands Mulets, there is nothing but glacier, and the materials could only be transported on the backs of men. A shelter was constructed at Grands Mulets to serve as a depot of supplies and refuge for the porters. The trail from this station to the Rocher Rouge, which is only about 300 meters below the summit, formed the third section, and there was constructed here a hut for the carpenters and others engaged on the work to pass the nights and take refuge in case of bad storms.

All the summer of 1892 was employed in the construction of the observatory, its removal to Chamonix, and the partial completion of the mountain transportation; and in the year 1893 all was up, at a total cost of 40,000 francs. An accident just failed of ruining the whole venture, for a depot of material, situated at Rocher Rouge, had disappeared by spring, and was finally found buried beneath 8 or 9 meters of snow.

For some months the great glacier of Mont Blanc, whose profile stands like a gigantic staircase, appeared like a woodyard with its

files of porters, and the workers of the windlass, which were placed from point to point to aid in moving the heavier pieces over the dangerous declivities. When the material was finally in place the carpenters from Meudon began its erection, and, favored by a fortnight of calm weather, they were able to complete their work on the 8th of September. M. Janssen, eager to see the work, resolved to undertake another ascension, in which he availed himself of the windlasses this time to drag his sledge. He reached the top on the 11th, about midday, and remained there four days, occupied principally with observations of the solar spectrum, formed by a fine Rowland grating.

Janssen undertook another ascent in 1895, with the principal object of making sure that all the parts of the large telescope of 33 centimeters aperture for the observatory, had come up in good condition, and were in shape to pass the winter without injury. This telescope is mounted in connection with a polar siderostat, so that its axis is parallel with the axis of the earth and receives the light reflected from the siderostat mirror. Both the mirror, of 60 centimeters diameter, and the objective were presented by the Henry brothers. All the adjustments are controlled from the observer's station, who thus has no need to move about, and may remain in a closed room kept at a comfortable temperature. This beautiful instrument, whose mechanical parts were constructed by Gautier, was mounted not without some difficulty in 1896. M. Janssen also inspected the registering meteorograph, which had been installed in 1894, but had stopped. This instrument was constructed by M. Jules Richard, and is driven by a weight of 90 kilograms, which falls 5 or 6 meters in eight months and keeps in motion a pendulum which regulates the motion of the registering mechanism. There is continuous registration of the barometric pressure, temperature, humidity, and velocity and direction of the wind. It proved that the apparatus lacked stability, and it ran after being given a support independent of the flooring, but the instrument has never gone very regularly. Another meteorograph, also designed to go eight months without rewinding, has been installed at Grands Mulets.

The problem of securing a very long running meteorograph suitable to be placed on a high mountain as a substitute for observations during the bad season is one of great delicacy, which requires further trials. M. Janssen is much interested in it and has proposed a new form, in which the rotation and fall of a registering cylinder is brougth about by its own weight. M. Poncet, professor of horology at the college of Cluses, is engaged with the construction of a meteorograph of this kind. Up to the present time no registering meteorograph has been run more than eight or nine months.

At the time of this last visit Janssen made measurements to determine what, if any, movements of the observatory building had occurred since its erection. It proved that there had been a slight movement in the direction of Chamonix, but according to one of the builders this movement took place in 1893 and 1894, and afterwards ceased. There appears to have been no very appreciable amount of settling, and at all events there are means provided for correcting this if it should occur; so that the fears and doubts expressed by Alpinists as to the safety of the observatory have proved unfounded. The architect Baudouin, who visited the observatory on July 9, 1906, found it buried in snow on the south side, but this had occasioned no injury to the construction, so that the floor of the observing room, which was dressed off in 1904, is still perfectly true. It seems therefore that the question of construction on a snow foundation at high altitudes is well settled.

III.

Since his last ascent M. Janssen has returned to Chamonix each year to direct the work which the younger men have carried on at Grands Mulets and Mont Blanc. The observatory has been made sufficiently comfortable to allow of observing visits of even a fortnight duration. There is no lack of subjects for researches, for the study of the planets Venus and Mercury, the solar and stellar spectra, the chemical and heating effects of the radiation of celestial objects engage the attention of astronomers, while meteorology and physiology offer problems equally interesting for solution at high altitudes. M. Janssen has frequently communicated to the Academie des Sciences short papers summarizing the results obtained.

We may mention in the first place the researches on the heating effect of solar radiation, which forms one of the objects of the observatory of Mont Blanc. A principal aim of such researches, which are performed by aid of instruments called actinometers or actinographs, is to fix the value of the "solar constant." This is the number which gives in calories per square centimeter per minute the heating powers of the sun's rays before their entrance into our atmosphere. In the older treaties on physics there is assigned a value less than 2 calories (1.763), which comes down from the researches of Pouillet with his pyrheliometer. But the tendency was later to augment this value. M. Violle, having made in August, 1875, an ascent of the Bosson glacier and of Mont Blanc, estimated 2.54 calories. M. Crova, the able physicist of Montpellier, finds 2.83 calories from observations on Mont Ventoux. In 1881, Langley, having observed near the summit of Mount Whitney, which has an altitude of 4,460 meters, inferred from his experiments a value exceeding 3 calories. Savélieff, at

Kiev, found 3.5, and Knut Ångström, who observed on Téneriffe, proposed to adopt 4 calories.[a]

These discordances result in part from a diversity of modes of observation, but partly also by the variability of the condition of the atmosphere, owing to the presence of water vapor, of dust, and of snow, carried by the wind. Such impurities, often invisible, are chiefly found in the lower layers of the atmosphere, and as they cause a powerful absorption, which diminishes the energy of the rays, it is sought to avoid them by observing at high altitudes and in calm, cold weather.

In 1896 Messrs. Crova and Houdaille made experiments at Chamonix (altitude 1,050 meters) and at Grands Mulets (3,020 meters). These observations were repeated the following year by M. Hansky, a young Russian attached to the staff of the observatory at Meudon. He observed successively at Brévent, Grand Mulets, and the summit of Mont Blanc, employing the apparatus of M. Crova, and under the latter's advice. The discussion of the observations led him to the value of 3.4 calories. He repeated the work in 1898, 1900, and 1904, and has reached the result 3.3 as the most probable value of the solar constant. He believes that it is certainly between 3.0 and 3.5 and in any case above the value 2.5 calories,[a] which Langley has lately obtained with his bolometer. It is clear that the physicists are not in accord as to the true value of

---

[a] It seems fair to Ångström and to Langley to state the following additional facts. Ångström proposed the value 4 calories not as a result of his observations of 1895 and 1896 on Téneriffe, but as a result of inferences which he made in 1890 regarding the influence of the carbonic acid gas of the atmosphere in diminishing the solar radiation. The progress of investigation convinced him of the error of these inferences, and he publicly and unreservedly withdrew the proposed value 4 calories in a footnote to an article published in 1900 (Annalen der Physik, vol. 3, p. 721, 1900).

Langley's value, 3 calories, depends on an inference which he made in 1881 of a failure of Bouguer's formula for allowing for atmospheric absorption, even when applied to homogeneous rays. Nevertheless he made no correction in his later papers for this, like that by which, in 1881, he raised his value of the solar constant from 2.2 to 3 calories, nor is any justified. The value of 2.5 calories is taken from an article published by him in 1903, and this single value was distinctly stated to be only provisional in character. In 1904 he published (Astrophysical Journal, Vol. XIX, p. 305, 1904) a list of twenty-five values, all lying between 1.93 and 2.28 calories, which constitutes his last word on the subject, and this list includes the result which had been stated at 2.5 calories, but which on a more careful reduction came at 2.2 calories. The substantial correctness of these values is confirmed by simultaneous observations in 1905 and 1906 at Washington and Mount Wilson. From the apparent accuracy of the work, and the comparison with temperatures upon the earth's surface he was led to consider that there might have occurred a real variation of the sun of nearly 15 per cent, as indicated by the divergence of the values.—(TRANSLATOR.)

the solar constant, if indeed it be constant, for to be sure no one has proved that the solar radiation is not variable. It would be of interest also to study in an analogous manner the chemical effectiveness of the solar radiation and also of its photometric brightness, all of which comprises a great field of observation.

We have already discussed at some length the observations of Janssen relative to the question of the existence of oxygen on the sun and the confirmation of his results by the experiments of Comte de la Baume-Pluvinel. In 1899 new experiments on the photography of the spectrum were undertaken by Tikhoff, an astronomical assistant at Meudon, and these included observations at Meudon, Chamonix, and the summit of Mont Blanc. In 1902 Aubert carried on a piece of work in which he employed a spectroscope having lenses and prisms of quartz, for the purpose of studying the modification of the intensity of the ultra violet part of the spectrum caused by change of altitude, a piece of work which was begun by Cornu. Finally, in 1905 and 1906, M. Stefanik, of the University of Prague, made spectral observations in the same conditions.

In 1895 and 1896 one of the most experienced of the astronomers of the Paris Observatory, M. Bigourdan, attempted with the Defforges apparatus to measure the force of gravity at the summit of Mont Blanc and at different points in the region; but his experiments were hindered by bad weather. They were repeated in 1898 by M. Hansky with the apparatus of Sterneck, which is well adopted for relative determinations. The measurements were conducted first at Meudon, then on the summit of Mont Blanc and at Grands Mulets, Brévent, and Chamonix.

In 1900 M. Hansky came once more from Russia to repeat his actinometric observations, and he ascended the mountain for that purpose on July 23 and September 1, spending six days on the summit at each visit. On September 4 he had occasion to observe the sun at rising, and saw the famous green ray. He writes: "The atmosphere was transparent, and the horizon of an extraordinary clearness, so that mountains more than 100 kilometers distant could be seen distinctly. At the instant of sun rising I was struck by an intense pure green light, which lasted about a half second. The sun appeared directly after, brilliant and all yellow without a tinge of red. Hygrometric observations showed a very low percentage of water vapor in the atmosphere and there were few solid particles." It is well known that this phenomenon, which is sometimes observed on the open ocean in calm clear weather, is explained by the dispersion of the sun rays, which graze the horizon under conditions such that the green part of the spectrum is not unduly weakened by absorption. On the previous night M. Hansky had observed the occultation of Saturn by the moon,

and had noted the absence of any band or elongation between the planet and the lunar disk, which indicates the remarkable perfection of the seeing. In this connection it should be noticed that in 1904 M. Hansky made an interesting observation of the zodiacal light from Mont Blanc, when he perceived details very difficult to distinguish under any ordinary conditions. He has also attempted to photograph the solar corona, but the results have not been satisfactory, and will be repeated.

Messrs. Féry and Millochau have undertaken to determine the distribution of radiation over the solar disk, employing Féry's pyrometric telescope. This comprises a tube of variable aperture containing a silvered glass concave mirror; a thermoelectric couple in the focus connected with a galvanometer, and a prism which reflects a beam for guiding. Observations were made on Mont Blanc and at Chamonix and Meudon.

These examples will suffice to show that the observatory perched on the heights of Mont Blanc offers facilities to astronomers for the prosecution of a variety of special researches of great delicacy. But the scope of observations has little by little expanded, so as to comprise also meteorology and physiology. The work has usually to be carried on in the summer months, however, for the winters are apt to be too rigorous. In 1901 M. Nordmann found recorded by a Tonnelot minimum thermometer a temperature of —45° C.

Among experiments of other kinds which have been made in the past few years may be cited as particularly important some which were carried on in 1899 and 1900, with the support of the administration of the telegraph, to determine the insulating properties of ice. Bare wires of galvanized iron were laid upon the glacier at some meters apart. The experiments were commenced by Messrs. Cauro and Lespieau, and continued by Lespieau alone after the fatal accident of Cauro, who met with a terrible fall in a trail on the mountain of la Cote. The experiments showed that a telegraphic line of great length, such as 100 kilometers, for example, may be established with bare wire upon glaciers, and give good service. This result is of value for telegraphy on the high mountains, although there had been before trials of short lines laid on snow.

M. Maurice de Thierry made in 1894 and 1899 a series of determinations of the atmospheric ozone, ammonia, and carbonic-acid gas at different altitudes. M. Le Cadet, in 1902, studied the atmospheric electricity from the summit of Mont Blanc. M. Nordmann also tried to detect electromagnetic waves emanating from the sun, but with negative results. Of another nature are the spectroscopic studies of the blood commenced by Doctor Hénocque in 1902, and continued after his death by M. Raoul Bayeux; the observations of Messrs.

Guillemard and Moog on hyperglobulation at high altitudes, and finally, the bacteriologic study of the snow of Mont Blanc began in 1900 by Doctor Binot, of the Pasteur Institute. Doctor Binot found in different parts of the glacier a varied microscopic flora whose existence had hitherto been quite unsuspected, and promising to reward further study with many and curious results. Actinometric and physiological studies (among others, upon respiration at high altitudes) have been carried on by M. Vallot and the numerous scientists, both French and foreign, to whom he has offered the hospitality of his observatory des Bosses. Messrs. Joseph and Henri Vallot are now preparing to publish a map of the region of Mont Blanc.

I have restricted myself to giving, as it were, a bird's-eye view of the varied studies to which the creation of an observatory on Mont Blanc have given rise. It will surely be most desirable that its development and further equipment shall go on, in order that it may render all the services which are made possible by its unique situation. May it not be made more accessible, perhaps, by establishing communication by dirigible balloon between Chamonix and Mont Blanc?

THE PROBLEM OF THE METALLIFEROUS VEINS.[a]

By James Furman Kemp.[b]

The rush of the gold seekers to California in 1849 and the quickly following one to Australia in 1851 were notable migrations in search of the yellow metal, but they were not the first in the history of our race. There is, indeed no reason to suppose that in the past, mining excitements were limited even to the historical period; on the contrary, the legends of the golden fleece and of the golden apples of the Hesperides probably describe in poetic garb two of the early expeditions, and long before either we can well imagine primitive man hurrying to new diggings in order to enlarge his scanty stock of metals. Among the influences which have led to the exploration and settlement of new lands the desire to find and acquire gold and silver has been one of the most important, and as a means of introducing thousands of vigorous settlers, of their own volition, into uninhabited or uncivilized regions there is no agent which compares with it. In this connection it may be also remarked that there is no more interesting chapter in the history of civilization than that which concerns itself with the use of the metals and with the development of methods for their extraction from their ores. Primitive man was naturally limited to those which he found in the native state. They are but few, viz. gold in wide but sparse distribution in gravels; copper in occasional masses along the outcrops of veins, in which far the greater part of the metal is combined with oxygen or sulphur; copper, again, in porous rocks, as in the altogether exceptional case of the Lake Superior mines; iron in an occasional meteorite, which, if its fall had been observed, was considered to be the image of a god descended from the skies;[c] silver in occasional nuggets with the more common ones of gold; and possibly a rare bit of platinum. Besides these no other metal can have been known, because all the rest and all of those mentioned when locked up in their ores give in the physical

[a] Reprinted, by permission, from Economic Geology, Vol. I, No. 3, December–January, 1906. Economic Geology Publishing Company, Lancaster, Pa.

[b] Presidential address to the New York Academy of Sciences, read at the annual meeting in New York, December 18, 1905.

[c] As in the case of Diana of the Ephesians and the deity of the Carthaginians.

properties of the latter but the slightest suggestion of their presence. Chance discoveries must have first revealed the possibilities of producing iron from its ore—really a very simple process when small quantities are involved,—of making bronze from the ores of copper and tin, of making brass with the ores of copper and zinc, of reducing copper and lead from their natural compounds, and of freeing silver from its chief associate, lead. All of these processes were extensively practiced under the Chinese, Phœnicians, Greeks, Romans, and other ancient peoples.

As the need of weapons in war, the advantages of metallic currency, and the want of household utensils became felt, and as the minerals which yield the metals became recognized as such, the art of mining grew to be something more than the digging and washing of gravels, and in the long course of time developed into its present stage—as one of the most difficult branches of engineering. Chemistry raised metallurgical processes from the art of obtaining some of a metal from its ore to the art of obtaining almost all of it and of accounting for what escaped. It is, in fact, in this scientific accounting for everything that modern processes chiefly differ from those of the ancients.

Of all the metals the most important which minister to the needs of daily life are the following, ranged as nearly as possible in the order of their usefulness: Iron, copper, lead, zinc, silver, gold, tin, aluminum, nickel, platinum, manganese, chromium, quicksilver, antimony, arsenic, and cobalt. The others are of very minor importance, although often indispensable for certain restricted uses.

The manner of occurrence of these metals in the earth and their amounts in ores which admit of practicable working are fundamental facts in all our industrial development, and some accurate knowledge of them ought to be a part of the intellectual equipment of every well-educated man. The matter may well appeal to Americans, since the United States has developed within a few years into the foremost producer of iron, copper, lead, coal, and, until recent years, of gold and silver; but, with regard to gold, they have of late alternated in the leadership with the Transvaal and Australia, and in silver are now second to Mexico.

Despite the enormous product of foodstuffs, American mining developments are of the same order of magnitude, and the mineral resources of the country have proved to be one of the richest possessions of its people.

We may best gain a proper conception of the problem of the metalliferous veins if we state at the outset the gross composition of the outer portion of the globe, so far as geologists have been able to express it by grouping analyses of rocks. We may then note among the elements mentioned such of the metals as have just been cited,

and may remark the rarity of the others; we may next set forth the necessary percentages of each metal which make a deposit an ore; that is, make it rich enough for profitable working. By comparison we can grasp in a general way the amount of concentration which must be accomplished by the geological agents in order to collect from a naturally lean distribution in rocks enough of a given metal to produce a deposit of ore, and can then naturally pass to a brief discussion and description of those agents and their operations.

If the general composition of the crust of the earth is calculated as closely as possible on the basis of known chemical analyses, the following table results, which has been compiled by Dr. F. W. Clarke, of Washington, chief chemist of the U. S. Geological Survey: [a]

	Per cent.		Per cent.
Oxygen	47.13	Manganese	0.07
Silicon	27.89	Sulphur	.06
Aluminum	8.13	Barium	.04
Iron	4.71	Chromium	.01
Calcium	3.53	Nickel	.01
Magnesium	2.64	Strontium	.01
Potassium	2.35	Lithium	.01
Sodium	2.68	Chlorine	.01
Titanium	.32	Fluorine	.01
Hydrogen	.17		
Carbon	.13	Total	100.00
Phosphorus	.09		

Elements less than 0.01 per cent are not considered abundant enough to affect the total, and equally exact data regarding them are not accessible. Among those given only the following appear which are metals of importance as such in everyday life: Aluminum 8.13, iron 4.71, manganese 0.07, chromium 0.01, and nickel 0.01. They rank, respectively, in the table, third, fourth, thirteenth, sixteenth, and seventeenth. Of the five, iron is the only one of marked prominence. No one of the remaining four is comparable in usefulness with at least five other metals which are not mentioned, viz, copper, lead, zinc, silver and gold.

An endeavor has been made by at least one investigator, Prof. J. H. L. Vogt, of Christiania, to establish some quantitative expression for these other metals. His estimates are as follows: [b]

Copper percentage beyond the fourth or fifth place of decimals—that is, in the hundred thousandths or millionths of a per cent.

Lead and zinc percentages in the fifth place of decimals, or in the hundred thousandths of a per cent.

Silver percentage two decimal places beyond copper, or in the ten millionths to the hundred millionths of a per cent, or the ten thousandths to the hundred thousandths of an ounce to the ton.

[a] Bulletin 148, p. 13.

[b] Zeitschrift für prak. Geologie, 1898, p. 324.

Gold percentage one tenth as much as silver.

Tin percentage in the fourth or fifth decimal place—that is, in the ten thousandths or hundred thousandths of a per cent.

These figures, inconceivably small as they are, convey some idea of the rarity of these metals as constituents on the average of the outer 6 or 8 miles of the earth's crust. But they are locally more abundant in particular masses of eruptive rocks which are associated with ore deposits.

In the following tabulation I have endeavored to bring together a number of determinations which have been made in connection with investigations of American mining districts. In a general way they give a fair idea of the metallic contents of certain eruptive rocks from which were taken samples as little as possible open to the suspicion that they had been enriched by the same processes which had produced the neighboring ore bodies.

Ore.	Per cent in eruptive rocks.	From—	Ore.	Per cent in eruptive rocks.	From—
Copper	0.009	Missouri.[a]	Silver	0.00007	Leadville, Colo.[f]
Lead	.0011	Colorado.[b]	Do	.00016	Eureka, Nev.[c]
Do	.008	Eureka, Nev.[c]	Do	.00016	Rosita, Colo.[e]
Do	.004	Missouri.[a]	Gold	.00002	Eureka, Nev.[c]
Zinc	.0048	Leadville, Colo.[d]	Do	.00004	Owyhee County, Idaho.[g]
Do	.009	Missouri.[a]			

[a] Average of eight eruptives from Missouri, anal. by J. D. Robertson. Report on Lead and Zinc, Mo. Geol. Surv., II, 479.

[b] Average of six different rocks, embracing eighteen assays; S. F. Emmons, Monograph XII, U. S. Geol. Surv., 591.

[c] One rock, a quartz porphyry, not certain the rock was not enriched. J. D. Curtis, U. S. Geol. Surv., Mono. VII, 136.

[d] S. F. Emmons, XVII Ann. Rep. U. S. Geol. Surv., Part II, p. 471. The zinc was determined in but two samples.

[e] S. F. Emmons, XVII Ann. Rep. U. S. Geol. Surv., Part II, p. 471.

[f] Idem, p. 594.

[g] A. Simundi in Tenth Census, XIII, 54.

In order to come within the possible limits of profitable and successful treatment the ores of the more important metals should have at least the following percentages, but that we may grasp the relations correctly it must be appreciated that local conditions affect the limits. Thus in a remote situation and with high charges for transportation an ore may be outside profitable treatment, although it may contain several times the percentages of those more favorably situated. Iron ores in particular which are distant from centers of population are valueless unless cheap transportation on a very large scale can be developed, while gold in an almost inaccessible region, like the Klondike, may yield a rich reward, even when in quantities which, if expressed in percentages, are almost inappreciable.

The nature of the ore is also a factor of prime importance. Some compounds yield the metals readily and cheaply, while others, which in the case of the precious metals are often called base ores, require complicated and it may be expensive metallurgical treatment. The association of metals is likewise of the highest importance. Copper or lead, for example, greatly facilitates the extraction of gold and silver, whereas zinc in large quantities is a hindrance. Conditions also change. An ore which may have been valueless in early days may prove a rich source of profit in later years and under improved conditions. For instance, from 1870 for over twenty-five years Bingham Canyon in Utah yielded lead-silver ores and minor deposits of gold. It was known that in some mines low-grade and base ores of copper and gold existed, but the fact was carefully concealed, and in at least one instance the shaft into them was filled up, lest a general knowledge of the fact should unfavorably affect the value of the property. To-day, however, these ores are eagerly sought and their extraction and treatment in thousands of tons daily are paying good returns on very large capitalization. Another factor is the expense of extraction. If simple and inexpensive methods are possible, the area of profitable treatment is greatly widened. Thus gold may need little else than a stream of water or even a blast of air, whereas iron and copper require huge furnaces and vast supplies of coke and fluxes.

Iron ores are of little value in any part of the world unless they contain a minimum of 35 per cent iron when they enter the furnace, but if they are distributed in amounts of 10 to 20 per cent in extensive masses of loose or easily crushed rock in such condition that they can be cheaply concentrated up to rich percentages, they may be profitably treated and a product with 50 per cent iron or higher be sent to the furnaces. Nevertheless, speaking for the civilized world at large, it holds true that as an iron ore enters the furnace it can not have less than 35 per cent, and in America, with our rich and pure deposits on Lake Superior, two-thirds of our supply ranges from 60 to 65 per cent.

As regards copper, a minimum working percentage amid favorable conditions and with enormous quantities is usually about 3 per cent, but in the altogether exceptional deposits of the native metal in the Lake Superior region copper rock as low as three-fourths of 1 per cent has been profitably treated. This or any similar result could only be accomplished with exceptionally efficient management and with a copper rock such as is practically known only on Lake Superior. With the usual type of ore, not enriched by gold or silver, 2 per cent is the extreme, and in remote localities 5 to 10 may sometimes be too poor.

In southeast Missouri lead ores are profitably mined which have 5 to 10 per cent lead, but they are concentrated to 65 to 70 per cent before going to the furnace.

Zinc ores at the furnace ought not to yield less than 25 to 30 per cent, and when concentrated or selected they range up to 60 per cent.

The precious metals are expressed in troy ounces to the ton avoirdupois. A troy ounce in a ton is one three-hundredth of 1 per cent, and the amount is therefore very small when stated in percentages. If it be appreciated that in round numbers silver is now worth 50 to 60 cents an ounce and gold $20, some grasp may be had of values. Silver rarely occurs by itself. On the contrary, it is obtained in association with lead and copper, and the ores are, as a rule, treated primarily for these base metals and then from the latter the precious metals are later separated. In the base ores there ought to be enough silver to yield a minimum of $5, or 10 ounces, in the resulting ton of copper in order to afford enough to pay for separation. Now, in a 5 per cent ore of copper we have a concentration of 20 tons of ore to yield 1 ton of pig, or more correctly stated, so as to allow for losses, 21 tons to 1. We must therefore have at least 10 ounces of silver in the 21 tons, which implies a minimum of about one-half ounce per ton. Smelters will only pay a miner for the silver if he has over one-half ounce per ton in a copper ore. In a pig of lead, usually called base bullion, it is necessary for profitable extraction to have 15 ounces of silver. For smelting a lead ore we must possess at least 10 per cent lead and may have 70. It is therefore obvious that from 2 to 20 ounces of silver must be present in the ton of lead ore. The common ranges are 10 to 50 ounces, or one-thirtieth to one-sixth of 1 per cent.

Gold is so cheaply extracted that it may be profitably obtained under favorable circumstances down to one-tenth of an ounce in the ton, but the run of ores is from one-fourth ounce, or $5, to 1 ounce, or $20. Ores of course sometimes reach a number of ounces. In copper or lead ores even a twentieth of an ounce may be an object, and in favorably situated gravels to which the hydraulic method may be applied even as little as 7 to 10 cents in the cubic yard may be recovered, or some such value as one two-hundredth to one three-hundredth of an ounce per ton.

The tin ores as smelted contain about 70 per cent, but they are all concentrated either by washing gravels in which the percentage is one or less, or else by mining, crushing, and dressing ore in which it ranges from 1.5 to 3 per cent. The tin-bearing gravels represent a concentration from much leaner dissemination in the parent veins and granite. Aluminum ores yield as sold about 30 per cent of the metal. This is an enrichment as compared with the rocks, though not so striking a one as in the case of other metals. But the great change

necessary in aluminum is in the method of combination. It is so tightly locked up in silicates in the rocks as to preclude direct extraction by any known method.

Nickel needs to be present in amounts of several per cent, say 2 to 5, and occurs either alone or with copper. Cobalt is always with it in small amounts. Platinum occurs in exceedingly small percentages. It is almost all obtained from gravels in Russia, and the gravels yielded in 1899, according to C. W. Purington, about 40 cents to the yard, platinum being quoted in that year at \$15 to \$18 per ounce. There was therefore in the gravels about one-fortieth ounce in the yard, or one-sixtieth in a ton or about five and a half hundred thousandths of a per cent. Platinum in some rocks has been found in amounts of one-twentieth to one-half ounce, or from sixteen hundred thousandths to sixteen ten thousandths of 1 per cent, but they are rare and peculiar types.

In order to be salable manganese ores of themselves must yield about 50 per cent, but if iron is also present they may be as low as 40. Chromium has but one ore, and it must contain about 40 per cent. Of antimony, arsenic, and cobalt, it is hardly possible to speak, since, except perhaps in the case of the first, they are unimportant by-products in the metallurgy of other ores.

In summary it may be stated that in the ores the metals must be present in the following amounts:

	Percentage in ores.	Ounces to ton.	Percentage in earth's crust.
Iron	35 to 65	....	4.71
Copper	2 to 10	....	.0000X
Lead	7 to 50	....	.0000X
Zinc	25 to 60	....	.0000X
Silver	$\frac{1}{12}$ to $\frac{1}{150}$	2 to 25	.000000X
Gold	$\frac{1}{300}$ to $\frac{1}{5000}$	$\frac{1}{20}$ to 1	.0000000X
Tin	1 to 3	....	.000X to .0000X
Aluminum	30	....	8.13
Nickel	2 to 5	....	.01
Manganese	50	....	.07
Chromium	40	....	.01

We now have before us some fundamental conceptions from which as a point of departure we may set out upon the real discussion of the subject. We understand the gross composition of the outer earth; we have some idea of the quantitative distribution of the metals in the rocks, especially in the richer instances; finally we have seen the extent to which they must be concentrated in order that they may be objects of mining. The next step is to establish, first, the agent or solvent which can effect the collection of the sparsely distributed

metals, and second, the places where the precipitation of them takes place. We may then inquire more particularly into the source of the agent and the methods of its operation. In order to do this in the time at command I must remorselessly focus attention on the large and essential features, resolutely avoiding every side issue or minor point, however inviting.

The one solvent which is sufficiently abundant is water, and practically all observers are agreed that for the vast majority of ore deposits it has been the vehicle of concentration. Of course it need not operate alone. On the contrary, easily dissolved and ever-present materials like alkalies may, and undoubtedly do, increase its efficiency. It does not operate necessarily as cold water. On the contrary, we all know that the earth grows hotter as we go down, so that descending waters could not go far without feeling this influence. Volcanoes, too, indicate to us that there are localities where heat is developed in enormous amounts and not far below the surface. There is therefore no lack of heat and we need only be familiar with the western country to know that there is no lack of hot springs when we take a comprehensive view. As solvents, hot waters are so incomparably superior to cold waters that they appeal to us strongly. We may therefore take it as well established that water is the vehicle. The chemical compounds which constitute the ores naturally differ widely in solubility and no sweeping statements can be made regarding them. Iron, for example, yields very soluble salts and is widely, one might almost say universally, distributed in ordinary waters. Its ores are compounds of the metal with oxygen and in this respect it differs from nearly all others, which are mostly combined with sulphur. Although almost all of them have oxidized compounds, the latter are on the whole very subordinate contributors to our furnaces.

Iron is everywhere present in the rocks and when exposed to the natural reagents it is one of their most vulnerable elements. It therefore presents few difficulties in the way of solution and concentration by waters which circulate on or near the surface and which perform their reactions under our eyes.

The compounds of copper, lead, zinc, silver, nickel, cobalt, quicksilver, antimony, and arsenic with sulphur present more difficult problems and ones into whose chemistry it is impossible to enter here in any thorough way, but in general it may be said that the solutions were probably hot, that they were in some cases alkaline, in others acid, and that the pressure under which they took up the metals in the depths has been an important factor in the process. The loss of heat and pressure as they rose toward the surface no doubt aided in an important way in the result.

The first condition for the production of an ore deposit is a waterway. It may be a small crack, or a large fracture, or a porous

stratum, but in some such form it must exist. Naturally porous rock affords the simplest case and provides an easily understood place of precipitation. For example, in the decade of the seventies rather large mines at Silver Reef in southern Utah were based upon an open-textured sandstone into which and along certain lines silver-bearing solutions had entered. Wherever they met a fossil leaf or an old stick of wood which had been buried in the rock the dissolved silver was precipitated as sulphide or chloride. Sometimes for no apparent reason the solutions impregnated the rock with ore, but the ore seems to follow along certain lines of fracturing. Again, at Silver Cliff, near Rosita, in central Colorado, the silver solutions had evidently at one time soaked through a bed of porous volcanic ash and had impregnated it with ore, which, while it lasted, was quarried out like so much rock. In the copper district of Keweenaw Point, on Lake Superior, the copper-bearing solutions have penetrated in some places an old gravel bed and impregnated it with copper; in other places they have passed along certain courses in vesicular lava flows and have yielded up to the cavities scales and shots of native copper.

It has happened at times that the ore-bearing solutions, rising through some crevice, have met a stratum charged with lime, and having spread sideways have apparently been robbed of their metals because the lime precipitated the valuable minerals. In the Black Hills of South Dakota there are sandstones with beds of calcareous mud rocks in them. Solutions bringing gold have come up through insignificant-looking crevices called "verticals" and have impregnated these mud rocks with long shoots of valuable gold ores. In prospecting in a promising locality the miner, knowing the systematic arrangement of the verticals, and having found the lime shales, drifts along in them, following a crevice in the hope of breaking into ore. The very extended and productive shoots of lead-silver ores at Leadville, Colo., which have been vigorously and continuously mined since 1877, are found in limestone and usually just underneath sheets of a relatively impervious eruptive rock. They run for long distances, and suggest uprising solutions which followed along beneath the eruptive, perhaps checked by it, so that they have replaced the limestone with ore. The limestone must have been a vigorous precipitant of the metallic minerals.

The fracture itself up through which the waters rise may be of considerable size and thus furnish a resting place for the ore and gangue, as the associated barren mineral is called. A deposit then results, which affords a typical fissure vein. The commonest filling is quartz, but at times a large variety of minerals may be present and sometimes in beautifully symmetrical arrangement. In the latter case the uprising waters have first coated each wall with a layer. They have then changed in composition and have deposited a later

and different one, and so on until the crack has become filled. Often cavities are left at the center or sides and are lined with beautiful and shining crystals, which flash and sparkle in the rays of a lamp like so many gems. There are quartz veins in California which are mined for gold and which seem to have filled clean-cut crevices, wall to wall, for several feet across. More often there is evidence of decided chemical action upon the walls, which may be impregnated with the ore and gangue for some distance away from the fissure. As the source of supply is left, however, the impregnation becomes less and less rich and finally fades out into barren wall rock. The enrichment of the walls varies also from point to point, since where the rock is tight the solutions can not spread laterally, but where it is open the impregnation may be extensive. The miner has, therefore, to allow for swells and pinches in his ore.

Of even greater significance than the lateral enrichment is the peculiar arrangement of the valuable ore in a vein that may itself be continuous for long distances, although in most places too barren for mining. Cases are, indeed, known in which profitable vein matter has been taken out continuously for perhaps a mile along the strike, but they are relatively rare. The usual experience reveals the ore running diagonally down in the vein filling and, more often than not, following the polished grooves in the walls, which are called "slickensides" and which indicate the direction taken by one wall when it moved on the other during the formation of the fracture. The rich places may terminate in depth as well and again may be repeated, but they must be anticipated, and for them allowance must be made in any mining operation.

Ores therefore gather along subterranean waterways. They may fill clean-cut fissures wall to wall; they may impregnate porous wall rocks on either side; they may even entirely replace soluble rocks like limestones.

We may now raise the question as to the source of the water which accomplishes these results, and the further question as to the cause of its circulations.

The nature of the underground waters, which are instrumental in filling the veins, presents one of the most interesting, if not the most interesting, phase of the problem, and one upon which attention has been especially concentrated in later years. The crucial point of the discussion relates to the relative importance of the two kinds of ground waters—the magmatic, or those from the molten igneous rocks, and the meteoric, or those derived from the rains. The magmatic waters are not phenomena of the daily life and observation of the great majority of civilized peoples, and for this reason they have not received the attention that otherwise would have fallen to their share. Relatively few geologists have the opportunity to view vol-

canoes in active eruption, and have but disproportionate conceptions of the clouds and clouds of watery vapor which they emit. The enormous volume has, however, been brought home to us in recent years with great force by the outbreak of Mont Pelée, and we of this Academy, thanks to the efforts of our fellow-member, Dr. E. O. Hovey, of the American Museum of Natural History, have had them placed very vividly before us. It is on the whole not surprising that to the meteoric waters most observers in the past have turned for the chief, if not the only, agent. I will therefore first present, as fully as the time admits and as fairly as I may, this older view, which still has perhaps the larger number of adherents.

Except in the arid districts, rain falls more or less copiously upon the surface of the earth. The largest portion of it runs off in the rivers; the smallest portion evaporates while on the surface, and the intermediate part sinks into the ground, urged on by gravity, and joins the ground waters. Where crevices of considerable cross section exist, they conduct the water below in relatively large quantity. Shattered or porous rock will do the same, and we know that open-textured sandstones, dipping down from their outcrops and flattening in depth, lead water to artesian reservoirs in vast quantity. As passages and crevices grow smaller the friction on the walls increases and the water moves with greater and greater difficulty. When the passage grows very small movement practically ceases. The flow of water through pipes is a very old matter of investigation, and all engineers who deal with problems of water supply for cities or with the circulation of water for any of its countless applications in daily life must be familiar with its laws. Friction is such an important factor that only by the larger natural crevices can the meteoric waters move downward in any important quantity or with appreciable velocity. They do sink, of course, and come to comparative rest at greater or less distance from the surface and yield the supplies of underground water upon which we draw.

The section of the rocks which stands between the surface and the ground water is the arena of active change and is that part of the earth's crust in which the meteoric waters exercise their greatest effect. Rocks within this zone are in constant process of decay and disintegration. Oxidation, involving the production of sulphuric acid from the natural metallic sulphides, is actively in progress. Carbonic acid enters also with the meteoric waters. The rocks are open in texture and favorably situated for maximum change. From this zone we can well imagine that all the finely divided metallic particles, which are widely and sparsely distributed in the rocks, go into solution and tend to migrate downward into the quiet and relatively motionless ground water. If the acid solutions escape the pre-

cipitating action of some alkaline reagent, such as limestone, they may even reach the ground waters, and their dissolved burdens may be contributed to this reservoir, but the greater portion seems to be deposited at the level of the ground water itself or at moderate distances below it. Impressed by these phenomena, which present a true cause of solution, and influenced by their familiar and everyday character, we may build up on the basis of them a general conception of the source of the metallic minerals dissolved in those aqueous solutions which are recognized by all to be the agents for the filling of the veins.

Let us now focus attention on the ground water. This saturates the rocks, fills the crevices, and forces the miner who sinks his shaft to pump, much against his natural inclination. The vast majority of mines are of no great depth, and the natural conclusion of our earlier observers, based on this experience, has been that the ground waters extend downward, saturating the strata of the earth to the limit of possible cavities, distances which vary from 1,000 to more than 30,000 feet. To this must be added another familiar phenomenon. The interior temperature of the earth increases at a fairly definite ratio of about 1° F. for each 60 to 100 feet of descent. In round numbers, if we start with a place of the climatic conditions of New York—that is, with a mean annual temperature of about 51°—we should on descending 10,000 feet below the surface find a temperature of about 212°, and if we go still deeper, it would be still greater. Of course, under the burden of the overlying column of water, the actual boiling points for the several depths would be greater, and it is a question whether the increase of temperature would overcome the increase of pressure and the consequent rise of the boiling point so as to convert this water into steam, cause great increase in its elasticity, decrease in its specific gravity, and thereby promote circulations. At all events, the rise in temperature would cause expansion of the liquid, would disturb equilibrium, and to this degree would promote circulations.

There is one other possible motive power. The meteoric waters enter the rocky strata of the globe at elevated points, sink downward, meet the ground water at altitudes above the neighboring valleys, and establish thereby what we call "head." In consequence they often yield springs. If we imagine the head to be effective to considerable depths we have again the deep-seated waters under pressure, which after their long and devious journey through the rocks may cause them to rise elsewhere as springs. The head may in small degree be aided by the expansion of the uprising heated column, whose specific gravity is thereby lowered as compared with the descending colder column.

May we now draw all these facts and supposed or assumed phenomena into one whole?

The descending meteoric waters become charged with dissolved earthy and metallic minerals in their downward, their deep-seated lateral, and perhaps also at the beginning of their heated uprising journey. They are urged on by the head of the longer and colder descending column and by the interior heat. They gather together from many smaller channels into larger issuing trunk channels. They rise from regions of heat and pressure which favor solution, into colder regions of precipitation and crystallization. They deposit in these upper zones their burden of dissolved metallic and earthy minerals and yield thus the veins from which the miner draws his ore.

This conception is based on phenomena of which the greater part are the results of everyday experience. It is attractive, reasonable, and is on the whole the one which has been most trusted in the past. Doubtless it has the widest circle of adherents today. It is, however, open to certain grave objections, which are gaining slow but certain support.

The conception of the extent of the ground water in depth, for example, is flatly opposed to our experience in those hitherto few but yearly increasing deep mines which go below 1,500 or 2,000 feet. Wherever deep shafts are located in regions other than those of expiring but not dead volcanic action, they have passed through the ground water, and if this is carefully impounded in the upper levels of the mines and not allowed to follow the workings downward, it is found that there is not only less and less water but that the deep levels are often dry and dusty. Along this line of investigation, Mr. John W. Finch, recently the State geologist of Colorado, has reached the conclusion, after wide experience with deep mines, that the ground waters are limited, in the usual experience, to about 1,000 feet from the surface and that only the upper layer of this is in motion and available for springs.

Artesian wells do extend in many cases to depths much greater than this and bring supplies of water to the surface, but their very existence implies waters impounded and in a state of rest.

To this objection that the ground waters are shallow it has been replied that when the veins were being formed the rocks were open-textured and admitted of circulation, but subsequently the cavities and waterways became plugged by the deposition of minerals by a process technically called cementation, and the supply being cut off, they now appear dry. There must, however, in order to make the "head" effective, have once been a continuous column of water which introduced the materials for cementation. It is at least difficult to

understand how a process, which could only progress by the introduction of material in very dilute solution should, by the agency of crystallization, drive out the only means of its production. Some residue of water must necessarily remain locked up in the partially cemented rock. This residue we of course do not find where rocks are dry and drifts are dusty. In many cases also, where deep cross cuts have penetrated the fresh wall rock of mines, cementation, if present, has been so slight as to escape detection.

If we once admit that this conclusion is well based, it removes the very foundation from beneath the conception of the meteoric waters and tumbles the whole structure in a heap of ruins.

While I would not wish to positively make so sweeping a statement as this about a question involving so many uncertainties, there is nevertheless a growing conviction among a not inconsiderable group of geologists that the rocky crust of the earth is much tighter and less open to the passage of descending waters than has been generally believed and that the phenomena of springs which have so much influenced conclusions in the past affect only a comparatively shallow, overlying section. Such phenomena of cementation as we see are probably in large part due to the action of water stored up by the sediments when originally deposited and carried down by them with burial. Under pressure a relatively small amount of water may be an important vehicle for recrystallization.

It has been assumed in the above presentation of the case of the meteoric waters that they are able to leach out of the deep-seated wall rocks the finely disseminated particles of the metallic minerals, but the conviction has been growing in my own mind that we have been inclined to overrate the probability of this action in our discussions. In the first place, our knowledge of the presence of the metals in the rocks themselves is based upon the assay of samples almost always gathered from exposures in mining districts. The rock has been sought in as fresh and unaltered a condition as possible and endeavors have been made to guard against the possible introduction of the metallic contents by those same waters which have filled the neighboring veins. But if we admit or assume that the assay values are original in the rock, and, in case the latter is igneous, if we believe that the metallic minerals have crystallized out with the other bases from the molten magma, we are yet confronted with the fact that their very presence and detection in the rock shows that they have escaped leaching, even though they occur in a district where underground circulations have been especially active. From the results which we have in hand it is quite as justifiable to argue that the metals in the rocks are proof against the leaching action of underground circulations as that they fall victims to it. These considera-

tions tend to restrict the activities of the meteoric waters to the vadose region, as Pošepný calls it, i. e., that belt of the rocks which stands between the permanent water level and the surface. Within it is an active area of solution, as we have all recognized for many years, but, as previously stated, experience shows that the metals which go into solution in it strongly tend to precipitate at or not far below the water level itself.

It is of interest, however, to seek some quantitative expression of the problem, and the assays given above furnish the necessary data.

I have taken the values of the several metals which have been found by the assays of what were in most cases believed to be normal wall rocks, selecting those of igneous nature, because experience shows them to be the richest. The percentages have been turned into pounds of the metal per ton of rock. This latter value has then been recast into pounds of the most probable natural compound or mineral in each case. I have next calculated the volume of a cube corresponding to the last weight, and by extracting its cube root have found the length of the edge of such cube. If now we assume a rock of a specific gravity of 2.70, which is a fair average value, and allow it 11 to 12 cubic feet to the ton, or, say, 20,000 cubic inches, the edge of the cube-ton will be 27.14 inches. The ratio of the edge of the cube of metallic mineral to the edge of the cube-ton of inclosing rock will give us an idea of the chance that a crack large enough to form a solution waterway will have of intersecting that amount of contained metallic mineral. Of course in endeavoring to establish this quantitative conception I realize that the metallic mineral is not in one cube, and that through a cube-ton of rock more than one crack passes, but I assume that the fineness of division of the metallic mineral practically keeps pace with the lessening width and close spacing of the crevices. It is also realized that the shape of the minerals is not cubical. I am convinced from microscopic study of rocks and the small size of the metallic particles that their subdivision certainly keeps pace with any conceivable solution-cracks, and that no great error is involved in the first assumption made. The sides of a cube represent three planes which intersect at right angles and which are mathematically equivalent to any series of planes intersecting at oblique angles. Hence, if we consider as cubes the subdivisions formed in our rock mass by any series of intersecting cracks, there are three sets of planes, any one of which might intersect the cube of ore. We must therefore multiply the ratio of probability that any single set will intersect it by three in order to have the correct expression. The chance that a crack of the width of the cubic edge of the inclosed mineral will strike that cube is given by the ratios in the last column, which ratios I assume hold good with increasing fineness of subdivision both of metallic minerals and of cracks.

	Per cent by analysis.	Pounds per ton.	Pounds chalcopyrite.	Volume (cubic inches).	Edge of cube.	Ratio of edge to edge of cube-ton rock.	Ratio of probability.
Copper	0.009	0.18	0.52	3.42	1.5	1/18	1/6
Lead (galena)	.0011	.022	.025	.092	.45	1/60	1/20
	.008	.16	.186	.700	.89	1/31	1/10
	.004	.08	.002	.340	.70	1/39	1/13
Zinc (zincblende)	.0048	.096	.128	.90	.97	1/35	1/12
	.009	.180	.240	1.60	1.17	1/21	1/7
Silver (argentite)	.00007	.0014	.0016	.006	.18	1/148	1/49
	.00016	.0032	.0037	.014	.24	1/113	1/38
Gold	.00002	.0004	.0004	.00065	.086	1/313	1/104
	.00004	.0008	.0008	.00130	.109	1/249	1/83

From the table it is evident that the chances vary from a maximum in the case of copper of 1 in 6 through various intermediate values to a minimum for gold of 1 in over 100. This is equivalent to saying that with cracks whose total width bears the same relation to the width of the rock mass as is borne by the diameter of the particle of ore, the chance of crossing a particle varies from 1 in 6 to 1 in 100. Or we may say that with cracks of this spacing from one-sixth to one one-hundredth of the contained metallic mineral might be leached out.[a] When, therefore, as is often the case in monographs upon the geology of a mining district, inferences are drawn as to the possibility of deriving the ore of a vein by the leaching of wall rocks whose metallic contents have been proved by assay, the total available contents ought to be divided by a number from 6 to 100, if the above reasoning is correct.

This diminution will tend to modify in an important manner our belief in the probability of such processes as have been hitherto advocated. We may justly raise the following questions: How closely set, as a matter of fact, are the cracks which are large enough to furnish solution waterways in the above rocks, and can we reach any definite conception regarding their distribution? Some quantitative idea of the relations may be obtained from the tests of the recorded absorptive capacity of the igneous rocks which are employed as building stone. G. P. Merrill in his valuable work on Stones for Building and Decoration, page 459, has given these values for 33 granites and 4 diabases and gabbros. They vary for the granites from a maximum of one-twentieth to a minimum of one seven-hundred-and-fourth. I have averaged them all and have obtained one

[a] With regard to the flow of waters through crevices and the relation of the flow to varying diameters or widths, a very lucid statement will be found in President C. R. Van Hise's valuable paper in the Transactions of the American Institute of Mining Engineers, XXX, 41, and in his Monograph on Metamorphism.

two-hundred-and-thirty-seventh as the result. That is, if we take a cubic inch of granite and thoroughly dry it, it will absorb water up to one two-hundred-and-thirty-seventh of its weight. The volume of this water indicates the open spaces or voids in the stone. The average of the specific gravities of the 33 granites is 2.647. If by the aid of this value we turn our weight of water into volume, we find that its volume is one-ninetieth that of the rock. For the four diabases and gabbros, similarly treated, the ratio of absorption is one three-hundred-and-tenth: the specific gravity is 2.776 and the ratio of volume one one-hundred-and-tenth. We can express all this more intelligibly by saying that if we assume a cube of granite and if we combine all its cavities into one crack passing through it, parallel to one of its sides, the width of the crack will be to the edge of the cube, as 1 to 90. In the diabases and gabbros, similarly treated, the ratio will be 1 to 110. These values are very nearly the same as the average of the ratios of the edges of the cubes of rock and ore given in the table on page 202, it being 1 to 104. We may conclude, therefore, that in so far as we can check the previous conclusion by experimental data it is not far from the truth.

It may be stated that the porphyritic igneous rocks which have furnished nearly all the samples for the above analyses are as a rule extremely dense, and that their absorptive capacity is more nearly that of the compact granites than the open-textured ones. It is highly improbable that underground water circulates through these rocks to any appreciable degree except along cracks which have been produced in the mechanical way, either by contraction in cooling and crystallizing or by faulting and earth movements. The cracks from faulting are very limited in extent, and in the greater number of our mining districts they affect but narrow belts, small fractions of the total. Of the cracks from cooling and crystallizing those of us who have seen rock faces in crosscuts and drifts underground where excavations have been driven away from the veins proper can form some idea if we eliminate the shattering due to blasting. My own impression is that in rocks a thousand feet or so below the surface such cracks are rather widely spaced, and that when checked in a general way by the ratios just given these rocks are decidedly unfavorable materials from which the slowly moving meteoric ground waters (if such exist) may extract such limited and finely distributed contents of the metals.

I have also endeavored to check the conclusions by the recorded experience in cyaniding gold ores in which fine crushing is so important, and I can not resist the conviction that we have been inclined to believe the leaching of compact and subterranean masses of rock a much easier and more probable process than the attainable data warrant.

As soon, however, as we deal with the open-textured fragmental sediments and volcanic tuffs and breccias the permeability is so enhanced as to make their leaching a comparatively simple matter. Yet so far as the available data go they are poor in the metals or else are open to the suspicion of secondary impregnation. They certainly have been seldom, if ever, selected by students of mining regions as the probable source of the metals in the veins.

Should the above objections to the efficiency of the meteoric waters seem to be well established, or at least to have weight, it follows that the arena where they are most, if not chiefly, effective is the vadose region, between the surface and the level of the ground water. Undoubtedly from this section they take the metals into solution and carry them down. But it is equally true that they lose a large part of this burden, especially in the case of copper, lead and zinc, at or near the level of the ground water and are particularly efficient in the secondary enrichment of already formed but comparatively lean ore bodies.

Let us now turn to the magmatic waters. That the floods of lava which reach the surface are heavily charged with them there is no doubt. So heavily charged are they that Prof. Edouard Suess, of Vienna, and our fellow-member, Prof. Robert T. Hill, of New York, have seen reason for the conclusion that even the oceanic waters have in the earlier stages of the earth's history been derived from volcanoes rather than, in accordance with the old belief, volcanoes derive their steam from downward percolating sea water. From vents like Mont Pelée, which in periods of explosive outbreaks yield no molten lava, the vapors rise in such volume that cubic miles become our standards of measurement.

There is no reason to believe that many of the igneous rocks which do not reach the surface are any less rich, and when they rise so near to the upper world that their emissions may attain the surface we must assign to the resulting waters a very important part in the underground economy.

This general question has attracted more attention in Europe in recent years as regards hot springs than in America. So many health resorts and watering places are located upon them that they are very important foundations of local institutions and profitable enterprises. Professor Suess, whom I have earlier cited, delivered an address a few years ago at an anniversary celebration in Carlsbad, Bohemia, in which he stated that Rosiwal, who had studied the Carlsbad district, could not detect any agreement between the run of the rainfall and the outflow of the springs, and that both the unvarying composition and amount through wet seasons and dry were opposed to a meteoric source. Water, therefore, from subterranean

igneous rocks, well known to exist in the locality, was believed to be the source of the springs. The same general line of investigation has led Dr. Rudolf Delkeskamp, of Giessen, and other observers to similar conclusions for additional springs, so that magmatic waters have assumed a prominence in this respect which leaves little doubt as to their actual development and importance.

All familiar with western and southwestern mining regions know as a matter of experience that the metalliferous veins are almost always associated with intrusive rocks, and that in very many cases the period of ore formation can be shown to have followed hard upon the entrance of the eruptive. The conclusion has therefore been natural and inevitable that the magmatic waters have been, if not the sole vehicle of introduction, yet the preponderating one.

With regard to their emission from the cooling and crystallizing mass of molten material we are not perhaps entirely clear or well established in our thought. So long as the mass is at high temperatures the water is potentially present as dissociated hydrogen and oxygen. We are not well informed as to just what is the chemical behavior of these gases with regard to the elements of the metallic minerals. Hydrochloric acid gas is certainly a widely distributed associate. If, as seems probable, these gases can serve, alone or with other elements, as vehicles for the removal of the constituents of the ores and the gangue, the possibilities of ubiquitous egress are best while the igneous rock is entirely or largely molten. In part even the phenomena of crystallization of the rock-forming minerals themselves may be occasioned by the loss of the dissolved gases. Through molten and still fluid rock the gases might bubble outward if the pressure were insufficient to restrain them and would, were their chemical powers sufficient, have opportunity to take up even sparsely distributed metals.

On the other hand, if their emission, as seems more probable, is in largest part a function of the stage of solidification and takes place gradually while the mass is congealing or soon thereafter, then they must depart along crevices and openings whose ratio to the entire mass would be similar to those given above. They might have and probably do have an enhanced ability to dissolve out in a searching and thorough manner the finely distributed metallic particles as compared with relatively cold meteoric waters which might later permeate the rock, but as regards the problem of leaching, the general relations of crevices to mass are much the same for both, and it holds also true that the discovery of the metals by assay of igneous rocks proves that all the original contents have not been taken by either process.

We may, however, consider an igneous mass of rock as the source of the water even if not of the ores and gangue, and then we have

a well established reservoir for this solvent in a highly heated condition and at the necessary depths within the earth. Both from its parent mass and from the overlying rocks traversed by it, it may take the metals and gangue.

In the upward and especially in the closing journey, meteoric waters may mingle with the magmatic, and as temperatures and pressures fall, the precipitation of dissolved burdens takes place and our ore bodies are believed to result. Gradually the source of water and its store of energy become exhausted; circulations die out and the period of vein formation, comparatively brief, geologically speaking, closes. Secondary enrichment through the agency of the meteoric waters alone remains to influence the character of the deposit of ore. In brief, and so far as the process of formation of our veins in the western mining districts is concerned this is the conception which has been gaining adherents year by year and which, on the whole, most fully accords with our observed geologic relations. It accords with them, I may add, in several other important particulars upon which I have not time to dwell.

In closing I may state that speculative and uncertain as our solution of the problem of the metalliferous veins may seem, it yet is involved in a most important way with the practical opening of the veins and with our anticipations for the future production of the metals. Every intelligent manager, superintendent, or engineer must plan the development work of his mine with some conception of the way in which his ore body originated, and even if he alternates or lets his mind play lightly from waters meteoric to waters magmatic, over this problem he must ponder. On its scientific side and to an active and reflective mind it is no drawback that the problem is yet in some respects elusive and that its solution is not yet a matter of mathematical demonstration. In science the solved problems lose their interest; it is the undecided ones that attract and call for all the resources which the investigator can bring to bear upon them. Among those problems which are of great practical importance, which enter in a far-reaching way into our national life and which irresistibly rivet the attention of the observer, there is none with which the problem of the metalliferous veins suffers by comparison.

IRON-ORE RESERVES.[a]

By Charles Kenneth Leith,
Professor of Geology, University of Wisconsin.

The great increase in the world's annual consumption of iron, together with the attempts of large interests to acquire the known iron-ore reserves, have led to careful inventories of the world's supply of iron ore, its rate of depletion, and to speculations as to further supplies. Estimates of the time of exhaustion of the present known supply have varied widely, but have shown startling agreement in the short time assigned. During the present year there have appeared several discussions of the subject which merit especial attention.[b]

Professor Törnebohm estimates for the Swedish Government the iron-ore reserves of the world by countries, based on detailed figures for the individual districts, as follows:

Country.	Iron-ore reserve.	Metallic iron.
	Tons.	*Per cent.*
United States	1,100,000,000	45 to 67
Great Britain	1,000,000,000	25 to 34
Germany	2,200,000,000	30 to 45
Spain	500,000,000	40 to 56
Russia and Finland	1,500,000,000	20 to 65
France	1,500,000,000	....
Sweden	1,000,000,000	50 to 70
Austria-Hungary Other countries	1,200,000,000	....
Total	10,000,000,000	....

[a] Reprinted by permission from Economic Geology, Vol. I, No. 4, February–March, 1906. Economic Geology Publishing Company, Lancaster, Pa.

[b] Presidential address, by R. A. Hadfield. Delivered at the annual meeting of the Iron and Steel Institute at London May 11, 1905. Journ. Iron and Steel Inst., Vol. LXVII, No. 1, 1905, pp. 27–106.

The iron ore supply of the world, by Prof. Alfred Törnebohm, Teknisk Tidskrift, September, 1905. Translated in the Iron Age November 2, 1905, pp. 1158–1160.

The exhaustion of the world's metals, by N. S. Shaler, International Quarterly, Vol. II, 1905, pp. 230–247.

A world survey of iron and steel, by J. Stephen Jeans, secretary British Iron and Steel Institute.

A blue book of iron-ore deposits in foreign countries, by Llewellyn Smith. Compiled at the board of trade from diplomatic and consular reports, London, 1905.

Many will be surprised at the high figures given for the reserves in Great Britain and European countries. So much is heard of our own vast reserves and of the low grade of some of the foreign ores that we have come to think of the supply outside of North America as relatively small. The position of the United States is somewhat better than shown in the table when we take into account the grades of ore. By multiplying the figures by the average percentages of metallic iron given for each of the countries by Professor Törnebohm the result is as follows:

Country.	Metallic iron.	Country.	Metallic iron.
	Tons.		*Tons.*
United States	603,166,600	Spain	249,375,000
Great Britain	295,000,000	Russia and Finland	637,500,000
Germany	825,000,000	Sweden	611,538,460

It is believed that the reserves for the United States, and hence the total, are higher than indicated in this table, but before taking up this question we may consider conclusions that may be drawn from the figures as they stand.

President Hadfield, of the British Iron and Steel Institute, has prepared a diagram, showing the world's increase of pig-iron consumption since the fifteenth century and the projection of this rate for the next century on the rate of the last thirty years. If the same rate of increase hold for the next century as has held for the last thirty years, in the year 2000 the world's annual consumption of iron will be three and one-fourth times its present consumption. The total world's supply of iron ore now known, given as 10,000,000,000 tons by Törnebohm, will be exhausted in about fifty years. If the total be correct, about one-fourth of the world's known reserves have been used to the present time.

It is argued that the calculated rate of increase is not improbable because of the increased rate per capita of the countries now using iron, because of the normal increase of the population of these countries and because of the extension of the uses of iron through a much larger proportion of the world's population than now uses it ($12\frac{1}{2}$ per cent). If 38 per cent of the world's population were to require iron in the year 2000, this would account for the calculated increase of consumption.

However, this additional part of the world's population, especially in Asia, may find its own iron-ore supplies. No one would doubt that the world's reserves will be greatly increased by new discoveries in these relatively unexplored parts of the world.

Judging from the history of the development of the iron-ore

industry to the present time the reserves of unexplored countries are likely to be developed only so fast as the population requires it. In this case such new discoveries will not figure in the reserves available to the countries at present producing iron ore. The generalization might perhaps be made that each continent must ultimately depend on its own resources of iron ore and can not count, to any large extent, on drawing supplies from other parts of the world.

It is of interest to apply the same method of calculation used for world's supply and consumption to the United States. If the rate of increase of consumption be projected for the next one hundred years on the basis of the increase for the past thirty years—that is, the period used by President Hadfield, and the lines superposed upon his diagram—it would appear that the rate of increase of production for the United States is greater than that of the world. Also the rate of production for the United States is greater than that of any other country. With the total reserve of iron ore in the United States estimated by Törnebohm at 1,100,000,000 tons, the supply would be exhausted in less than twenty years if the calculated rate of increase of production holds.[a] With the reserve estimated by Törnebohm, up to the present time 39 per cent of our total supply has been used, and 29 per cent has been produced during the last thirty years.

The late Edward Atkinson estimated that if the per capita consumption remains the same the average annual increase in population of 2,000,000 for the United States calls for a yearly increase of pig iron of half a million tons, and that when the probable increase in per capita consumption is taken into account the total production of the United States will increase at a considerably greater rate.

Professor Shaler concludes that the iron-ore supplies of the United States are not likely to last for more than a century.

Others have reached similar conclusions as to the relatively early exhaustion of the ore deposits, few venturing to predict a longer life for the known deposits of more than one hundred years. The strenuous efforts of larger interests in recent years to secure ore deposits and to explore ore-bearing fields are evidence that the possibility of the early exhaustion of the ores is appreciated by many of the companies most concerned.

The situation is probably not so unfavorable as the above estimates would indicate. The assigned rate of increase of production may be too great, for the development of the iron industry of the United States for the past thirty years has been a phenomenal one.

---

[a] Dr. William Kent calculates a pig-iron production of 67,340,000 tons in the year 1920 on the basis of the rate of increase of production since 1880. Iron Trade Review, Jan. 10, 1907, pp. 72–78.

On the other hand, it is scarcely safe to predict a lessening rate of increase, for during the past fifty years it has been thought many times that the increase of rate was checked.

Törnebohm's estimate of the total reserves of iron ores for the United States is very conservative, and probably should be greatly increased. His estimate is confined to the producing districts and leaves out of account many important extensions of the ore deposits and districts, many known deposits of good size and quality not now mined because of location or other causes, and large reserves of ore which in the United States are regarded as too low grade to be of present commercial value, but really of a higher grade than ores counted in the English and German reserves. There should also be included the iron-ore resources of Canada and Mexico immediately adjacent and accessible to the United States, already largely controlled by American capital and probably to be used in part in the United States.

The ultimate iron-ore resources of North America are still far from known, but there may be no harm in reviewing our present imperfect state of knowledge concerning them.

A great bulk of the known reserves of the United States is in the Lake Superior region. Törnebohm assigns a billion tons to the Lake Superior region, and these figures, while probably small, are in accord with many current estimates. In the producing Lake Superior iron districts exploration has, for the most part, been sufficiently thorough to make it certain that no large increase of reserves is to be expected. In the Mesabi Range, for instance, 30,000 drill holes and pits have been sunk. The Lake Superior iron districts, however, make up but a small proportion of the region tributary to Lake Superior, constituting less than 4 per cent of the land area included in the U. S. Geological Survey's map of the Lake Superior region. In the remaining 96 per cent there are still large possibilities for finding iron ores. The greatest of the ranges was discovered as late as 1891, and within the last four years two entirely new ranges have been found, though neither of them yet of the first importance. The geological conditions are such as to warrant the belief that more may be found. At the present time exploration in areas intervening between the ranges and in outlying areas is being pushed vigorously, showing the faith of iron men in further possibilities in this direction. The most sanguine, however, would scarcely hope to find ores equal in amount to those already known.

Lake Superior geological conditions are known to extend northward and northeastward through Ontario, suggesting an important source of supply here. The present known iron-ore supply of this

great region, counting even ores of low grade, does not equal the reserves of one of the older Lake Superior districts, such as the Marquette, but the country still to be explored is so vast that it is not unreasonable to suppose that important iron ranges such as those of the Lake Superior region may be found. Nevertheless, it is true that nowhere in the Lake Superior country where an equivalent amount of exploration has been done have the results been so disappointing.

When the present high-grade deposits of this and other countries are exhausted, the future demand for iron ore is likely to be met by the use of far lower grades than are now considered commercially profitable. The term " ore " is a relative one. With the conditions in Alabama a rock containing 36 per cent metallic iron may be mined as ore, while in the Lake Superior country such rock is now of no value as an ore. The ferruginous cherts and jaspilites, making up 95 per cent or more of the iron formations of the Lake Superior region, average between 25 and 35 per cent in metallic iron, and show all gradations into the iron ores. At the present time ores running below 45 per cent are but rarely shipped. If the time should come when 30 per cent ore could be used under the Lake Superior conditions, the tonnage available would be something enormous, perhaps twenty or more times as great as the present supply. It should be remembered that these ores are high in silica, and therefore not as desirable as ores of the same metallic content containing calcium carbonate in the gangue as do the Alabama ores. Moreover, the great distances from blast-furnace centers, on the assumption that these remain approximately fixed, will put the low-grade Lake Superior ores to a disadvantage in the matter of the cost of transportation.

Törnebohm estimates the amount of ore now available in the southern Appalachians at 60,000,000 tons. The Clinton red hematites make up the bulk of this tonnage. Drilling has shown that the presently worked deposits extend with slightly leaner but uniform composition in thin even beds over enormous areas, and it is altogether likely that the tonnage of these ores is many fold the figure given.[a] The ores are low grade, and the cost of mining will greatly increase when the larger reserves are tapped.

The Clinton ores extend along the Appalachians into New York and appear again in Nova Scotia and Newfoundland. In each of these localities extensions are likely to be found. At Belle Isle, Newfoundland, approximately 30,000,000 tons of iron ore are available. This body is known to extend under the ocean, and if it can

---

[a] E. C. Eckel estimates 1,000,000,000 tons of red ore above the thousand-foot level in Alabama alone. (Engineering Magazine, Vol. XXX, 1906, p. 521.)

be successfully mined there, a large additional tonnage may be secured.

The brown ores of the eastern United States are difficult to estimate. They are usually low grade, mixed with clay, and often lie in thin and irregular beds, but the aggregate amount is large.

The magnetites of the Adirondacks and New Jersey are not included in Törnebohm's figures. Here again the tonnage is large, and if attempts at magnetic separation are successful on a large scale, as they seem likely to be, we have here another important source of iron ore which has not been taken into account in these estimates.

The titaniferous magnetites will be another important source of supply when they can be profitably smelted.

Unexploited iron ore deposits are widely distributed in the western United States, and extravagant estimates of tonnage have been reported, frequently due to the fact that the basis of comparison has been the comparatively small size of the precious metal deposits of the West. The writer has examined deposits of reputed large size where the true tonnage seemed to him to be measured in units of thousands rather than millions or tens of millions. The grade of these deposits is on the average not high as compared with Lake Superior deposits, and there is frequently a high percentage of phosphorus and sulphur. Nevertheless, there is in the aggregate through the western States a very large tonnage of iron ore of present commercial grade.

Among the better-known deposits might be mentioned those in the Hartville district of Wyoming and in Fierro, N. Mex., both of which are now being drawn upon; in Pitkin, Chaffee, Saguache, Lake and Gunnison counties, Colo.; in Iron County, Utah; in northeastern Washington, and in a number of localities in the Great Basin region of Nevada and California. There should be included also the ores of Vancouver and Texada islands, in British Columbia, which are largely controlled by American capital and will be used in the United States. The same remarks may apply to the Durango and other Mexican deposits. With few exceptions the western ores occur along the contacts of intrusive igneous rocks and limestone, and the extent to which the ores follow the contact in depth has not been shown. Hence the estimates of tonnage vary within very wide limits. The iron-ore deposits of Iron County, Utah, are among the larger and most typical of this class of ores. Here some 800 pits have been sunk, and it has been possible in recent detailed mapping to estimate with a reasonable approach to the truth the amount of ore of all grades appearing to the depth shown

by explorations or natural exposures. Using the Utah deposits as a basis of comparison and excluding the Mexican deposits which the writer has not seen, the tonnage of iron ore of all grades in each of the better-known districts of the West and adjacent parts of British Columbia would not surpass that of one of the older Lake Superior ranges; but it is extremely likely, as deep exploration of the presently known deposits continues and as further deposits are found, as they undoubtedly will be, that the aggregate tonnage of ore in the West will equal a considerable part of that of the Lake Superior region, and one would be rash to conclude that it is impossible that an amount of iron ore may be found in the West fully equivalent to that in the Lake Superior region.

If these data approximate the truth, there seems to be little cause of alarm that North America will really suffer for lack of iron ore for a considerably longer period than required for the exhaustion of the presently known tonnage, as estimated by Törnebohm and others, at the present rate of increase of production. The time of exhaustion is not likely to come before that calculated on the same basis for the world's reserves, and probably not then. It may be argued that the use of lower grade ores in Europe and England than in the United States is itself evidence that the exhaustion of reserves is further in the future for the United States than for Europe or England. But as it becomes more and more obvious that the end of the supply of higher grade ores in the United States is not indefinitely in the future, and may even be within a single lifetime, there is likely to be an increase in the tendency to conserve the higher grade ores, and especially the Bessemer ores, and draw more largely on the lower grade supplies, a tendency favored by the concentration of control in a few hands. This tendency has already become well defined, as shown by the fact that pig-iron production has not in recent years increased as rapidly as iron-ore production. It is not at all unlikely that even the next decade may see important changes in this direction. This will give value to properly located low-grade ores. It will ultimately mean higher cost for iron, changes in the relative importance of processes for conversion of iron, possible changes in the geographic distribution of different phases of the iron industry, and a modification of the relations of the North American iron trade with that of the rest of the world.

Professor Shaler concludes[a] that when the higher grade deposits of the world have been exhausted, "the cost of production will

[a] International Quarterly, Vol. II, 1905, pp. 230–247.

gradually increase as the lower grade ores and those remote from coal come into use. In the end we shall have to resort to concentrating processes, by which the iron ore is separated from the rock in which it is disseminated as grains. This upward grade in cost means a downward grade in the utility of the metal in the service of man. Finally, it may be some centuries from now, but surely we shall be forced to an economy in the use of the metal such as was exercised by folk two hundred years ago, when, save for what went down at sea, or rusted back to earth, none of it was lost to the arts. In this stage, when it becomes again a precious metal, iron may continue to be the helper of man for an indefinite period, but its power for help will be greatly diminished."

THE GEOLOGY OF THE DIAMOND AND CARBONADO WASHINGS OF BAHIA, BRAZIL.[a]

By Orville A. Derby.[b]

[Translated by J. C. Branner.]

A trip to the diamond washings of Brazil recently made by the writer afforded an opportunity for obtaining a general idea of the geologic structure of the basin of Rio Paraguassu, which in its upper part includes the principal diamond region of the State of Bahia—the so-called "Chapada Diamantina," or diamond plateau.

The Paraguassu River crosses four regions different from one another in their geologic make-up and in their topographic and economic features. The first of these regions includes the entire district about the headwaters of the river and its principal tributary, the Santo Antonio, and extends as far as the falls of Passagem de Andarahy; the second extends from this point to the village of Bebedouro, about 70 kilometers by the wagon road below Passagem and 20 kilometers above the terminal station on the railway at Bandeira de Mello; the third extends from Bebedouro to the city of Maragogipe, with a width of about 300 kilometers; and the fourth from the

[a] Reprinted, by permission, from Economic Geology, Vol. I, No. 2, November–December, 1905. Economic Geology Publishing Company, Lancaster, Pa.

[b] Prof. O. A. Derby, for many years State geologist of Sao Paulo, Brazil, was lately employed by the State of Bahia to report upon the geology of the part of the State from which the carbonados are derived. The present paper is translated from the report made to the governor and published in the Portuguese language in the Diario da Bahia of June 1 and June 3, 1905. It is the most important paper thus far published upon the geology of the carbonados. It does not deal with the origin of the diamonds and carbonados, for the deposits mentioned are clearly secondary, but the geologic structure of the region is of the greatest economic importance in connection with prospective mining. Other papers by Mr. Derby upon diamonds are as follows:

1. "Geology of the diamond," Am. Jour. Sci., XXIII, 97–99, 1882.

2. "Modes of occurrence of the diamond in Brazil," Am. Jour. Sci., XXIV, 34–42, 1882.

3. "The genesis of the diamond," Science, IX, 57–58, 1887.

4. "Brazilian evidence on the genesis of the diamond," Jour. Geol., VI, 121–146. Chicago, 1898.

last-named point to the mouth of the river, with a width of only a few kilometers.

The first region is composed essentially of heavy beds of hard yellowish sandstone which often pass into a conglomerate. These beds, of which the thickness is estimated at more than 500 meters, are profoundly disturbed, being thrown into folds that may be compared to the waves of the sea, and are also cut by faults with the uplift sides forming enormous steep-faced cliffs. It is therefore essentially a mountainous region of the Appalachian type.

The general elevation of the region is about 1,000 meters; some peaks and ranges rise from 200 to 500 meters above this level, while the deeper valleys are cut some 700 meters below it.

On account of the hardness of the rocks and of the disturbances (folds and faults) they have undergone the topography is extremely rough and the vegetation sparse, many of the ranges being almost bare of soil and consequently of plant life. Here and there are small areas of gentler topographic outlines where the decomposition of the rocks has furnished a thick soil, and these places are generally covered with a scrubby vegetation or with forests. On account of the sandy nature of the underlying rocks the soil of the region is generally weak and is better adapted to cattle grazing than to agriculture. As for mineral resources, the only ones thus far utilized are diamonds and carbonados, and the geologic structure affords but little hope of the existence of other minerals, except perhaps where some older series of rocks may happen to crop out.

The second region is made up partly of beds of yellowish sandstone rather similar in appearance to those of the first region, but for the most part softer, more clayey, and containing interbedded strata of limestone some tens of meters in thickness.

The thickness of this series seems to be from 200 to 300 meters, and the beds are approximately horizontal, though there have probably been some vertical displacements by means of faults.

On account of its geologic constitution the region is relatively flat and has a general elevation of from 500 to 600 meters. It is cut, however, by the valleys of the Paraguassu and its tributary, the river Una, which are some 200 and more meters below the general level.

The decomposition of the rocks is much more pronounced in this than in the first region, so that it is only on the steepest slopes that the character of the underlying rocks can be seen.

The limestone when concealed, as it generally is, often discloses its presence by the flinty segregations which clutter the roadways at places where they have been set free by the decomposition of the inclosing rock.

The soil cap over the region is generally quite thick, and supports forests which at many places are dense. Where the limestone comes

to the surface the soil is of a dark red color and of a tallowy consistency. This soil is preferred by the few planters of the region in spite of its being deficient in running water, which, as is usual in limestone regions, sinks through the fractures and caverns that abound in the rock.

The falls of the Paraguassu River, formed by the rocks of this region, yield diamonds and carbonados which are obtained by diving, but it is uncertain whether these stones are derived from the rocks belonging to this region or are brought down from the region above.

Nothing is known of any other minerals of economic importance with the exception of the limestone which has been used at many places for the making of lime.

It seems that the sandstone and limestone formation, which characterizes a zone of some tens of kilometers in width along the eastern base of the Serra das Lavras, extends toward the north and makes up a large part of the so-called Matto do Urobo and also toward the south in the limestone region of Brejo Grande. From an agricultural point of view this zone is probably the most promising of the central interior of the State of Bahia.

The third region is made up of gneissic rocks abundantly cut by plutonic eruptions apparently of the granitic type. Its lowest portions are between 200 and 300 meters above sea level. In view of its geologic constitution the extent of the relatively horizontal surface features along the river and railway is rather striking. Above the comparatively low and flat base rise hills and peaks to an elevation of 800 meters and more. The low parts along the railway are covered with characteristic vegetation called "satinga," but it seems that the more elevated portions are covered by forests and have the reputation of being fertile. The rapid passage of the writer through this zone upon the railway did not permit observations upon its agricultural capabilities or mineral resources, but at several places it was possible to note that the soil is thin even in flat places where a greater thickness was to have been expected, and that many of the granite hills were almost completely barren of vegetation. So far as can be judged from its geologic constitution it is to be expected that there are in places deposits of manganese, iron, graphite, and perhaps other minerals of economic value.

The fourth region is made up of beds of the soft sandstone of Cretaceous and Tertiary ages that characterize the Reconcavo regions of Bahia and offers but little of interest in the present study.

The diamonds (including in this term the carbonados which rarely if ever fail to accompany the true diamonds in the Bahia Chapada) are especially characteristic of the first region, while their sporadic occurrence in the second and third regions may plausibly be attrib-

uted to ancient or recent transportation from the first. In all the localities examined (Santa Isabel, Chique-Chique, Andarahy, Lencoes, and Palmeiras) their occurrence is intimately associated with a thick bed of conglomerate, which is near the middle of the sandstone formation above described. This conglomerate represents a deposit of pebbles formed at a remote geologic epoch in the same way that pebbles are formed at the present time, and the same as the incoherent conglomerates not yet turned into hard rock, in which the miners look for diamonds. At many places it is evident that a portion of the gravels worked by the miners is simply the conglomerate decomposed in situ without having undergone any recent transportation or rearrangement.

There is thus repeated in this region the phenomenon already observed in the State of Minas Geraes, where there are several important washings in decomposed conglomerate and where, as in Grao Mogol, diamonds have been found embedded in the hard conglomerate.

The recent and unconsolidated gravels naturally contain a mixture of the elementary materials derived from all the rocks observed in the neighborhood, but where they are richest it is evident that the greater part of these materials come from the conglomerate or "pedra cravada," as the miners call it, which seldom fails to outcrop in immediate contact or in close proximity to the most productive washings. It is thus evident that the great, if not the only repository of diamonds in the region, is the conglomerate or gravel fossilized and interbedded with the great sandstone series that characterizes the Serra das Lavras.

The heaviest bed of conglomerate exposes an average thickness of from 6 to 10 meters, but it contains at many places thin beds of fine-grained sandstone. As has been said, its position is near the middle of the great sandstone series, so that, in general terms, there are about 250 meters of sandstone above it and as much more below it. There are many waterworn pebbles scattered through the sandstone that overlies the conglomerate, as well as thin intercalated beds of genuine conglomerate, and these features give a conglomeratic character to all of the formation from the middle upward. It is not, however, characteristic of the lower sandstone, and, together with other circumstances, leads to the belief that a geologic division should be made at the base of the conglomerate and that the lower beds belong to an independent and older division than that above. It is also a striking fact that many of the pebbles and rolled blocks embedded in the conglomerate are identical with the rocks of the underlying beds.

The conglomerate offers a greater resistance to atmospheric influence than the beds associated with it, and for this reason it produces

LENÇOES, BUILT ON DIAMOND-BEARING GROUND.

A NATIVE NAKED DIVER PREPARING TO GO DOWN; SUSPENDED FROM THE ROPE IS A TUBE CONVEYING AIR TO A MAN IN DIVING SUIT ALREADY ON BOTTOM.

(From photographs by H. W. Furniss.)

FINAL CONCENTRATION AND WASH UP IN BATEIAS.

CONCENTRATING CASCALCHO WITH HOES IN DITCHES OF WATER.

(From photographs by H. W. Furniss.)

most of the escarpments and makes the topography extremely rough and picturesque.

The sandstone beds above the conglomerate are especially subject to weathering and are at many places trenched by valleys, in whose walls are exposed large surfaces of naked conglomerate. Thus along almost all the eastern base of the mountains in the region between Santa Isabel and Lencoes, over a distance of more than 60 kilometers, the conglomerate covers almost the entire slope of the mountain, like tiles on a slanting roof, and plunges with a dip of from 20° to 30° toward the east into the bottom of the valleys of the Piabas, Chique-Chique, Andarahy, and San Jose rivers that skirt the mountains through this region, while the opposite sides of the valleys are formed principally by beds of the upper sandstone.

On account of the folding of the series the beds are several times repeated along a line normal to the general orientation of the mountain range, which is north-south. These folds may be easily recognized by the conglomerate outcrops which on an east-west line are exposed at various places dipping now toward the east and now toward the west. Thus, for example, in the section mentioned between Santa Isabel and Lencoes the dip of the conglomerate is always toward the east, and it forms the entire eastern slope of the range, but on passing over the crest of the ridge it reappears with a western dip after an interval in which a great thickness of the beds of the lower sandstone is exposed.

After another break occupied by the beds of the upper sandstone (the conglomerate having passed beneath it) the same rock appears again in the vicinity of Palmares, when the diamond washings likewise reappear.

Judging from information gathered from others, the same thing happens with the ranges and washings of Chapada Velha, Santo Ignacio, and others that form a chain of diamond-bearing ridges extending to near the Rio Sao Francisco.

If it is true that the conglomerate, or ancient gravel, is the great repository of diamonds and carbonados in the Lavras region, it follows that the stock of these minerals still in existence must be enormous. The points of easiest attack thus far worked are insignificant in comparison with the masses of materials containing the precious stones still untouched.

It is evident, however, that only a relatively small part of this mass can be worked with profit by the processes now in use. It remains to be ascertained whether modern technology, by using the hydraulic power so abundant and so favorably situated in the region, affords a method of operation less expensive than the value of the products.

This question is one to be solved by the mining engineer rather than by the geologist, but it seems to the writer that the probabilities of a favorable solution are strong enough to justify serious studies and experiments.

Outside of the region of the Serra das Lavras, properly speaking, which ends on the east in the escarpment covered by the conglomerate extending from Lencoes in the direction of Santa Isabel, the diamond washings on land become rarer or are altogether wanting. At a few points, however, where the bed of Rio Paraguassu and some other places have been worked by diving, the locations are so far from the Serra that it is difficult to believe that the diamonds have been brought from there. The most important of these points is the falls of Funil near Bebedouro and consequently on the eastern margin of the region of sandstone and limestone above described. This fall is formed by a heavy bed of conglomerate quite like that of the diamond region, but which, it seems, must belong to another geologic horizon superior to that of the Serra. Its cobblestones are principally of granitic rocks and the conglomerate rests directly upon rocks of this kind. It seems probable that the diamonds found at this place come from the local conglomerate or from some of the rocks associated with it, but upon this point nothing could be conclusively determined.

As the geologic series of this second zone is more recent than that of the Serra and hence presumably formed in part of materials derived from it, there is a strong presumption that it is also here and there diamond-bearing. The " formation " or concentrated washings of these gravels taken from below the falls at Funil are quite different from those of Lavras in the greater abundance of granitic elements, presumably owing to the fact that streams flow in above from granitic and gneissic regions.

As to the geologic horizon to which the two (or three) series of rocks above indicated should be referred, nothing decisive was observed. Search for fossils that might have thrown light on this question was fruitless. For various reasons that will not be mentioned here, the writer judges them to be older than the secondary rocks to which are referred the diamond deposits of South Africa and those of the region of Bagagem, in Minas Geraes, and that they will eventually be found to belong to the middle or upper part of the Paleozoic.

The diamond region of Salobro, in the municipality of Cannavieiras, is especially interesting, for it differs notably from the other diamond-bearing regions of Brazil on account of its proximity to the sea (about 60 kilometers) and on account of the absence of marked topographic relief that is generally associated with the

occurrence of the diamond. The region is moderately hilly, with an elevation of a little more than a hundred meters, while the highest serras to be seen on the horizon have no apparent relation with the occurrence of diamonds in Rio Salobro. The entire region is covered by a thick soil that supports heavy forests, which conceal the rocks and render geologic observations difficult.

On the banks and at the falls of Rio Pardo, hardly 6 kilometers from the Salobro washings, it was ascertained that the underlying rocks of the region consist of a series of beds of sandstone and argillaceous shales, with a heavy bed of conglomerate made up of rolled blocks of different kinds of granitic and gneissic rocks. This series appears to have a thickness of several hundred meters and has a strong eastward dip.

In the beds of Rio Salobro and of its small tributaries this conglomerate is exposed at several places, and the washings thus far opened are all in the immediate vicinity of its outcrops. In order to verify the hypothesis of the conglomerate origin of the diamonds, Mr. Pedro Benazet kindly had washed separately about 1½ cubic meters of decomposed conglomerate, selected by the writer for the purpose. The result was a diamond weighing 3 grains. It thus seems to be beyond doubt that here in the littoral zone, as well as at Lavras, the diamond is directly associated with the conglomerate, which thus furnishes for prospecting a valuable guide, easily found and recognized.

It is evident that a formation as thick as that exposed on the rivers Pardo and Salobro must have a wide distribution in this zone, and there is a strong probability that at many, if not at all, points where it crops out, it contains diamonds as it does on the Salobro. Furthermore, this last district still affords a very large field for mining operations.

MAP OF VESUVIUS AND ITS SURROUNDINGS.

THE ERUPTION OF VESUVIUS IN APRIL, 1906.[a]

By A. Lacroix.

CONTENTS.

I.—Effusion of Lava and Explosive Phenomena.

GENERAL TYPES OF VOLCANIC ERUPTIONS.

A preliminary statement is necessary regarding the different types of volcanic eruptions.

The chemical composition of a magma is believed to be a more or less dominant factor in the dynamics of eruptions; violent explosions,

[a] Translation, in abstract, by permission of author and publisher, of article in Revue générale des Sciences, Paris, October 30, 1906, pp. 881–899; November 15, 1906, pp. 923–936.

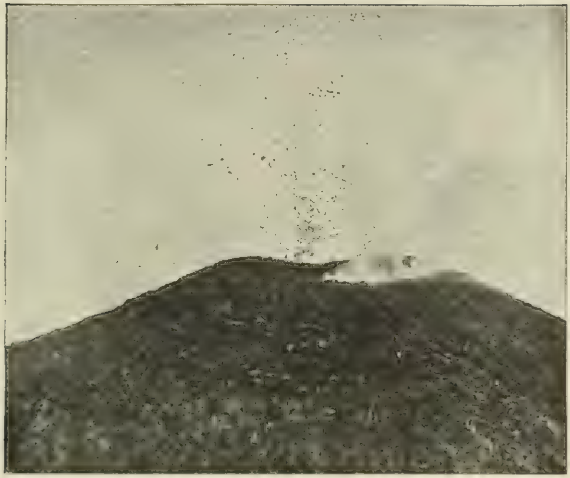
for example, being considered characteristic accompaniments of eruptions of acid magna. At Mont Pelée, however, the same magma sufficiently acid to form rocks rich in quartz, although not changing in composition with time, has been emitted as very liquid flows of considerable length, as masses of viscous lava accumulated around the orifice and accompanied with violent explosions, and finally as pumiceous material resulting from eruptions entirely explosive. The fact must be emphasized, therefore, that the form of eruption is determined not only by the chemical composition of the magma, but also by its physical condition, and by its fluidity or viscosity at the moment of eruption.

It is doubtless true, that, as the fusibility of a magma bears a relation to the chemical composition, a very basic magma tends to reach the surface in a more fluid condition than a very acid magma, but there are many conditions—velocity of emission, mass of material emitted, temperature, and abundance of volatile products, notably water vapor—which can modify the fundamental tendency and cause a volcano with very fusible lava to behave as a volcano with viscous lava, or vice versa. Former eruptions of Vesuvius, as well as that of 1906, furnish numerous arguments in support of this proposition.

The most fluid magma known is the basaltic lava of Kilauea and Mauna Loa. It is a thin, opaque liquid of great fluidity. The emission is accompanied by no violent explosions, and only by light vapors. This type has been called the *Hawaiian* type.

The fluidity of the basaltic magma of Stromboli is still great at the moment of eruption, although less than in the preceding case. The discharge of gases causes violent explosions, which throw into space fragments of the doughy magma, some of which fall upon the edges of the crater to flatten there, while other portions shape themselves in the air and fall as scoria, either in blocks or in fine dust. Rock fragments, already consolidated, caught in the magma, form elongated bombs. The ejected material shows its incandescence even in daylight, and at night forms admirable fireworks. Water vapor is often hardly apparent; when it is visible it forms white thin clouds. This type of explosion I designate with Mercalli the *Strombolian* type.

An altogether different type was realized in 1888–89 at Vulcano for which Mercalli has proposed the name *Vulcanian*. It is produced when at the moment of explosion the magma is very viscous or wholly consolidated; in the first case, the bombs have the bread-crust structure with a pumiceous center and a glassy exterior; in the second case, they are formed of angular blocks which on cooling become fissured by contraction. The clouds accompanying the *Vulcanian* explosions are very dense, opaque, gray or black, with outlines extremely well defined, and lightning is frequent among them. The



STROMBOLIAN EXPLOSION AT TERMINAL CONE OF VESUVIUS.

(Photograph by Mercalli.)

STROMBOLIAN BOMBS, BASALTIC VOLCANO OF GRAVENOIRE.
PUY DE DÔME.

VULCANIAN BOMBS (BREAD-CRUST STRUCTURE ON THE RIGHT).
ANDESITE FROM MOUNT PELÉE (1902).

VULCANIAN EXPLOSION RISING FROM THE CRATER OF VULCANO (1889).

(Photograph by Silvestri, contributed by Friedlander.)

solid matter transported by them, whatever its dimensions, is formed of fragments or dust of rock entirely consolidated. Perfect examples of Vulcanian clouds have been furnished by Vulcano (trachitic), Mount Pelée (andesitic), and by the recent eruption (April, 1906) of Vesuvius (leucitic).

This idea of Strombolian and Vulcanian explosions, although not formulated till the past few years, has been long recognized. Fouqué at the time of the eruption of Etna, in 1865, noted that some craters gave forth liquid lava with almost colorless vapors, whereas others ejected only solid materials and a thick mixture of water vapor and dust.

It is necessary, finally, to consider a variety of the Vulcanian type, which I will call *Peléean*. It differs essentially in that the proportion of solid materials carried away by the cloud is much greater, so that, instead of ascending vertically, as in the preceding case, it descends upon the flank of the volcano and flows or rolls upon the surface of the ground with accelerated velocity. Sometimes, as in the eruption of St. Vincent (1902) and the small eruptions of Mont Pelée, its motion is essentially the result of gravity alone; at other times, as in the great paroxysms of Mont Pelée, the cloud has been directed by an initial thrust and by gravity working in the same direction. A Peléean cloud is also animated by an ascensional movement due to the expansion of water vapor, but this is of secondary origin, and its direction is not the same as that of the initial thrust. The cloud ascends vertically as it rolls downward upon the surface of the slope.

I employ the term Peléean cloud as more general than that of burning cloud (nuée ardente), because similar clouds are conceivable at temperatures inferior to that characterizing the eruptions of the Antilles, although the high temperature undoubtedly plays an important part in the mechanism of the cloud and in the stability of the emulsion of solid material in the water vapor that characterizes it.

The different types of explosions form a continuous series. Further divisions are unnecessary, intermediate types being referred to as mixed explosions.

SEQUENCE OF PHENOMENA OF THE ERUPTION.

The recent eruption of Vesuvius (April, 1906) had been a long time in preparation. In April, 1905, the explosive activity of the volcano increased. At the bottom of the crater, at a depth of 80 meters, a small cone was found, which, by successive Strombolian explosions, had grown by the middle of May to a height of 15 meters above the edges of the old crater.

From May 25 to May 27 the Strombolian explosions increased in intensity. Violent detonations were heard, and during the evening of the 27th a fissure opened upon the northwest flank of the great cone at an elevation of 1,245 meters, upon the site of the fumaroles dating from the eruptions of August 26, 1903. Some hours later a new fissure opened at 1,180 meters altitude, and for nearly a month lava poured simultaneously from these two openings—an exceptional fact for Vesuvius, because an orifice in activity generally ceases as soon as another opens at a lower level. This outpouring of lava, however, with accompanying explosive phenomena, continued with maxima and minima of activity till April, 1906.

The 3d of April, 1906, heavy detonations were heard; on the 4th, at 5.30 a. m., earth movements were felt; then, while the fissure on the northwest flank was still active, a new one opened upon the south flank at an altitude of about 1,200 meters, and a small flow issued which ceased at evening. The activity of the fissure on the northwest flank had diminished, and ceased on the next day.

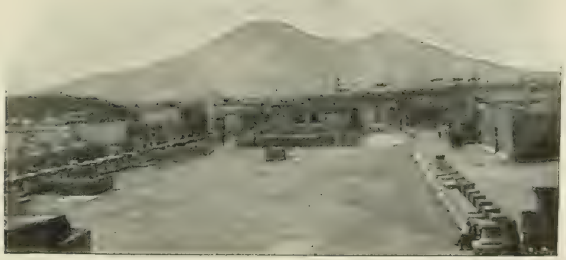
During the morning of the 4th, and till midday, the crater was the scene of explosions at first Strombolian and later Vulcanian. These last destroyed the small interior cone and commenced the destruction of the edges of the great cone. The dust formed by these explosions was transported to Naples during the night. Another opening formed on the south flank at an altitude of about 800 meters, and the flow which issued therefrom traveled 2.5 kilometers with a speed of 100 meters per hour.

On April 6, about 8 a. m., when all the other openings were inactive, a new one was formed on the southeast flank near Cognoli, at an elevation of about 600 meters, from which a flow issued with a width of 300 to 400 meters. A branch of this flow came to a point about 1 kilometer from Boscotrecase, traversing 3,800 meters in about thirty-two hours. This opening, and another on the 7th, furnished much of the lava that caused devastation in the plain. At the same time a new opening farther east was formed at an elevation of about 750 meters, furnishing a flow which spread over older lava fields. The flow issuing near Cognoli, already referred to, advanced through inhabited regions, and on April 8, at 4 p. m., stopped within a few meters of the cemetery of Torre Annunziata. All the inhabitants of the country traversed by it, with the exception of three, were able to save themselves. This great flow is 5.5 kilometers long and has an average width of 300 meters. A minor flow followed later during the night of April 10 from the same opening.

The lava flows issued for the most part in the region south of the cone from fissures opened successively lower on the flanks.

The outpouring of lava formed only a part of the activity. During the evening of the 7th violent detonations were heard at Naples.

PELÉEAN CLOUD DESCENDING FROM THE CRATER OF MOUNT PELÉE (1902).
HEIGHT, 2,000 METERS.



VESUVIUS AND SOMMA SEEN FROM THE FORUM OF POMPEII.
MAY 5, 1906.

FRAGMENTARY ASPECT OF THE FLOW SURROUNDING A HOUSE AT BOSCOTRECASE.

FRONT OF THE LAVA FLOW, HALTED IN ITS COURSE IN A STREET OF BOSCOTRECASE.

The Strombolian phase increased in intensity from 8 to 10.45 p. m. The incandescent material was elevated 2 kilometers above the crater. The outbursts succeeded each other so quickly that they seemed continuous and resembled fountains of fire. According to Mercalli, the summit of the mountain was covered with a continuous bed of incandescent material, from which blocks were constantly rolling to lower levels.

At 10.45 p. m., at the moment when the opening of Cognoli became most active, the crater seemed to calm itself for some minutes and then suddenly its activity became more furious than ever. At 12.31 a. m., and then at 2.40 a. m., great detonations were heard and earthquakes were experienced throughout the Vesuvian region. This was the maximum stage of the eruption, when the explosions passed from the Strombolian phase to the Vulcanian. The material ejected became less incandescent and finally was completely dark.

At this moment an enormous quantity of lapilli, mixed with blocks, was thrown northeast toward Ottajano. This fall of lapilli caused most of the fatalities of the eruption and destroyed much property.

The explosive maximum apparently coincided with the effusive maximum.

The ejection of lapilli lasted only a few hours, but at the same time and during the entire day of the 8th and the following days there were successive violent Vulcanian explosions, casting their solid materials upon the cone. The thick clouds of material brought darkness upon the flanks of the volcano, and the condensation of water vapor caused floods of mud.

These Vulcanian ejections, at first continuous and violent, gradually diminished in intensity and took place at rarer intervals, until about the middle of May, when they ceased.

During some days succeeding the paroxysm of the 8th the slopes were constantly enveloped in a thick cloud of dust. When it cleared away the form of the summit was seen to have been profoundly altered by the truncation of the cone, accompanied by a widening and deepening of the crater. This was the source of the enormous amount of material thrown out by the Vulcanian explosions.

The period of activity has been further characterized by the production of dry avalanches, by earth movements, and by intense electric phenomena, and it has been followed by torrents of mud and by exhalations.

The principal phenomena will now be considered in greater detail.

EFFUSION OF LAVA.

The flows of basic magma present an entirely different aspect, according to the temperature and velocity with which they are emit-

ted. Two types are common. Great streams that have spread out rapidly at a high temperature, and consequently in a condition of great fluidity, have a surface broken by very angular scoriaceous blocks. When, on the contrary, the magma flows slowly, its surface stretches or wrinkles, and finally breaks in places, allowing the molten material to exude. These lavas have a more or less even surface. Their progress is silent, whereas the others advance with a characteristic noise produced by collisions of the blocks.

The great flows of 1906 belong essentially to the first type. When I visited Boscotrecase, six days after the eruption, there were no observations possible upon the progress of the lava. It was still incandescent in places, however, and till April 24 it was possible to find cavities at the bottom of which glowed red-hot lava.

My observations of 1905 have been most valuable in permitting a better comprehension of the details observable in the lava field of Boscotrecase. In the evening of October 3, 1905, guided by Matteucci, I climbed to a point where lava was issuing from a tunnel a short distance below the fissure. The opening was hardly more than a square meter in diameter. The incandescent magma flowed rapidly, with a velocity of 6 meters a minute. It formed a straight torrent upon the steep slope of the cone. For the first 25 meters the surface was stretched in the direction of the flow. The fluidity was such that the lava was easily pierced by a stick, but great blocks of rock thrown upon this moving mass did not sink into it. They simply became fastened to the surface, firmly enough to maintain their position on the steep slope as they were carried away by the current. Beyond the first 25 meters solidified fragments began to appear on the surface, especially along the edges, where they formed a moraine. This increased rapidly in thickness and encroached upon the central part of the stream, which, at 100 meters from the source, was entirely covered with incandescent fragments.

The lava flowed continuously, without disturbance or effort, but at one moment we saw coming from the mouth of the opening a great fragment which emerged half way and then, caught by the current, plunged afresh into the moving magma, leaving behind it a swelling, which soon lost its circular shape by merging into the longitudinally striated surface of the surrounding lava. This block formed a large inclusion or pseudo-bomb.

At the base the flow became a fiery lake. It was an inspiring spectacle. From the incandescent torrent and the Strombolian ejections sheaves of a vivid red vaulted far above us, illuminating the darkness of the night, while at our feet in the distance glowed like small white stars the electric lights of Naples.

The surface of another flow studied by me, from a position as near as the radiation of heat would permit, exhibited a constant

THE LAVA FLOW UPON THE TRACKS OF THE CIRCUM-VESUVIAN RAILWAY.

LAVA FLOW FILLING THE CUT OF THE CIRCUM-VESUVIAN RAILWAY WITHOUT OVERFLOWING.

HOUSES OF BOSCOTRECASE ENTOMBED IN LAVA. THE PEOPLE SHOWN ARE ON A ROOF.

VULCANIAN EXPLOSION AT THE CRATER. WHITE VOLCANIC ASH MODELED BY THE WIND.

(Photograph by Brun.)

decrepitation of scoriaceous matter both coarse and fine. The accumulation of this material at the front of the flow is analogous to similar material upon the basaltic flows of Auvergne and might easily be taken for products of vertical ejections.

The lava fields of 1906 at Boscotrecase are roughened with scoriaceous blocks presenting strange forms. The surface is broken in places by higher asperities due to the escape of gas or by great slabs of lava broken by contraction and overturned by the continuous progress of the subjacent lava, and there are also fissures more or less profound. Among the surface blocks abound globular masses with compact crust and scoriaceous interior which have often been described as bombs, whereas they are fragments of old lavas caught up by the stream in the manner of the block above described.

The lavas of April 6 to 8 from the fissures of Cognoli followed the line of greatest slope. They filled ravines and minor depressions and formed, where the topography permitted, small secondary currents which in places reunited, leaving between them small oases of verdure. Near the source the current is very distinct and is bordered by black-covered moraines. The edges and front of the flow near Boscotrecase are formed of talus, with a height locally of several meters, ending abruptly in the midst of vineyards or among the habitations of the people.

The behavior of the lava in the cultivated and inhabited regions has been varied. Roads lined with walls at right angles to the greatest slope have been cut and the lava has in places gone some meters in the transverse direction. When the route was parallel or only slightly oblique to the direction of the flow the lava has flowed between the walls, and some of the streets of Boscotrecase are blocked by a high wall of lava. The railway with its cuts and fills has furnished obstacles or special facilities for the advance of the lava, some of the cuts having been completely filled. At some of the fills it has poured over the road and flowed in cascades down the farther slope. In one case the lava flowed under a railway bridge and stopped just in time to save it from serious damage. On cooling in this railway cut it has formed a sort of highway with an even surface some decimeters above the fields on either side. At 200 meters from the front of this flow the railway reaches a level surface which has been traversed by another ramification of the same flow. The two rails at this point have suffered a symmetrical deviation, due to expansion. Houses met various fates, according to their situation, some being destroyed. Others were invaded by the lava, which found an entrance through doors and windows facing the mountain. The lava was sufficiently fluid to fill the chambers and courts and to mold itself there. It is hardly necessary to add that although the

lava was sufficiently cool after a few days to allow access to the houses, the chambers not filled with it had a suffocating temperature.

The weak conductivity of the lava for heat explains why all combustible objects were not immediately consumed, but the carbonization of the woodwork proceeded slowly, contributing to the vapors emanating from the magma itself. The chimneys and the conduits of the gutters gave forth much smoke or currents of heated air. To this weak conductivity is due further the survival of trees hardly carbonized at the base, protected by a crust of lava that congealed rapidly at their contact. Investigations may reveal interesting mineralogical alterations in the houses that have been overwhelmed. In other instances devitrification of glass and crystallization of silver, zinc, and copper and the formation of new minerals have been observed, and such alterations will have a special interest in this instance from the leucitic nature of the lava.

All the particulars of the progress of the lava present a striking analogy to those of the thick flows of mud. This is easily explained by the fact that in both cases they are the result of fluidity of the mass in motion, due in the one case to temperature and in the other to the presence of water.

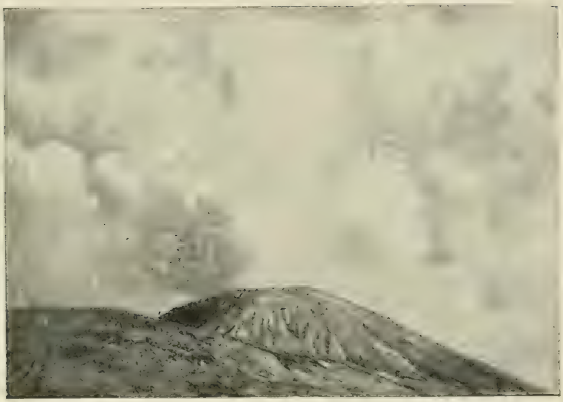
EXPLOSIVE PHENOMENA.

STROMBOLIAN EXPLOSIONS.

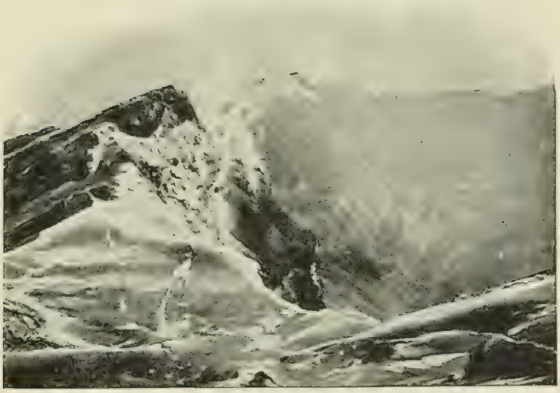
These present no special point of interest except their intensity during the night of April 7, in the course of which the emptying of the crater by the great flow brought them to an end. They furnished bombs and vitreous scoriæ, a part of which was very light. The form and structure of the material attest the great fluidity of the magma at the time of ejection. On my arrival these deposits were completely covered by the material of the Vulcanian explosions.

VULCANIAN EXPLOSIONS.

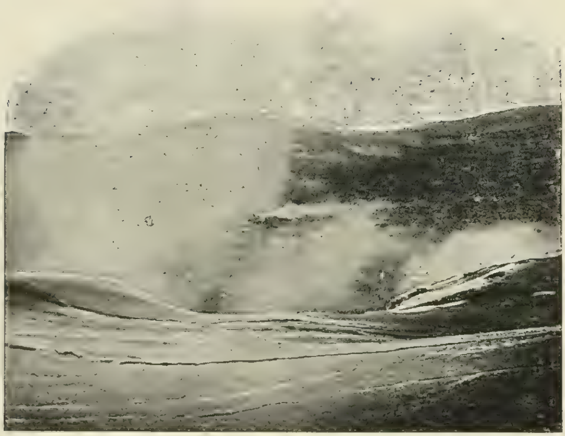
These in all respects form the chief interest of the eruption. Their characteristic traits have already been described. The enormous columns of clouds developed to a height of several thousand meters above the crater. Dense, gray or black in color, seamed by lightning, accompanied by heavy detonations, they were successfully thrust forth, the one into the other, like puffs from each stroke of a steam engine under strong pressure; later the ascension was less rapid; the columns rose majestically upward, merging into one another; still later they mounted slowly, then for some minutes remained stationary above the crater till dispersed by the wind. Avalanches of solid material descended from their base, but in no case did they become sufficiently dense to assume the Peléean form. Often in the



THE TERMINAL CONE MODIFIED BY THE ERUPTION.



THE CRATER NEAR THE NOTCH ON THE NORTHEAST SIDE, MAY 3.



THE CRATER AND THE FLOOR OF THE NOTCH, MAY 3.

THE CRATER. PHOTOGRAPH MADE TO THE RIGHT OF THE PRECEDING, MAY 3.

days following the chief paroxysm we passed hours watching these clouds. Starting from the crater they remained motionless on its edges, affecting at times a slight descending motion, which, however, was never completed. It seemed that in these cases a slight increase in density would have determined the formation of the Peléean clouds.

The Vulcanian explosions have been not only one of the most imposing spectacles of nature, but have had far-reaching results. They have formed a deep caldera; they have accumulated upon its edges an enormous mass of solid material of all dimensions, at the expense of which the dry avalanches have been formed; they have caused the disaster at Ottajano and San Giuseppe, and finally have sent into space much fine dust, which has covered the volcano with a thick bed, caused injury to agriculture throughout the region, and been transported by the wind to great distances from Vesuvius.

Formation of a caldera.—At the beginning of April a small cone had been constructed in the old crater, extending several meters above its summit, with an altitude of 1,335 meters above sea level. The Vulcanian explosions of April 4 destroyed this small ephemeral cone and dismantled the summit of the old cone. The paroxysm of April 8 and the following explosions produced the present crater. The operation was complex and embraced the following stages: First, the complete evacuation of the new magma, filling the central canal by the Strombolian ejections and especially by the formation of lateral flows; second, the shattering of the walls and enlargement; third, a sinking which carried with it the whole summit of the mountain; fourth, the ejection of the greatest part of the crumbling material.

One comprehends easily why the explosions were of the Vulcanian type. The interruption of free communication with the exterior brought about such a condition that the explosions were made in a solid medium, like that of very viscous or extremely consolidated lava, though in this case the mass to be raised was not essentially new magma but old débris. The main features of the crater were acquired at the end of the night of April 8, during the course of which the principal sinking of the summit took place, but the Vulcanian explosions continued much longer and ended by throwing out of the new cavity the material that partially obstructed it.

The section of the new crater is almost circular, with dimensions of 640 by 650 meters. The depth appears to be at least 300 meters. The walls are almost vertical, except near the surface, where they form a steep talus, and near the bottom, where they terminate in a funnel, the bottom of which is partly hidden by fumaroles. The crest is shattered, irregular, and sharp-edged. The highest side is on the northwest; the lowest is a deep notch 77 meters lower on the

northeast. This cut has a bottom several meters wide, which is very much shattered and which will probably fall into the crater. The minimum lowering of the mountain has been determined to be 103 meters, but the dimensions frequently change, the crater enlarging at the expense of its edges. The vertical walls of the crater present admirable sections showing the alternation of beds of fragmental material, ash, and lava, traversed by vertical or oblique dikes that characterize the internal anatomy of the cone.

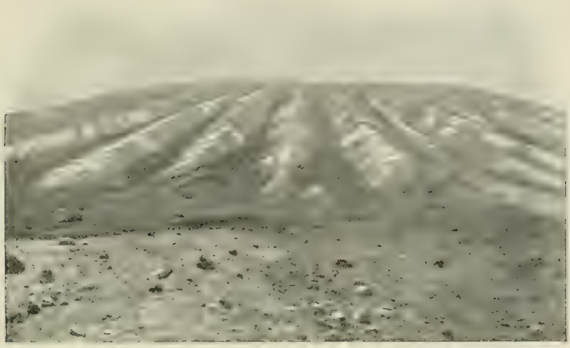
The crater of 1906 is remarkably like that of 1822, but its dimensions are less. That also had a notch on one side which, like that of the present crater, was located in line with fissures.

The wide and deep crater thus formed is a true caldera, and the phenomena of its production have a strong bearing on the mode of formation of this kind of volcanic mechanism. It is the more instructive in that the eruption is not an exceptional one. Accounts of the eruptions of 1631, 1761, 1779, 1839, 1850, and 1872 show that the same phenomena have been repeated with greater or less intensity. They constitute the characteristic traits of a special type of the great Vesuvian eruptions.

The caldera of Vesuvius is comparable to that of the Soufriere of St. Vincent and to the crater of Mount Pelée previous to the eruption of 1902. The V-shaped notch, which played so fatal a rôle in the destruction of St. Pierre, is the equivalent of that opened in the eruption of Vesuvius. It is noteworthy to see this feature, caused by the existence of fissures traversing the cone, repeat itself in different volcanoes.

Dry avalanches.—With the exception of the material that fell upon Ottajano and its surroundings, the products of eruption other than the fine dust have been thrown but a short distance. The sides of the crater have been covered several meters thick with a bed of blocks of all sizes up to several meters in diameter, minute fragments, and fine dust. The dry avalanches have been produced either by direct ejection of material from the crater or by the loosening of material already accumulated on the slopes, and the latter method has apparently been predominant. In the most active phase avalanches could be seen to detach themselves from the summit, but it was impossible to observe their point of departure.

The avalanches roll along the surface, followed by a train of light dust, and are easily distinguishable from the dense, clear-cut Peléean clouds, which expand vertically in the course of their downward progress. The mechanism of the avalanches is easily understood. The profile of the cone is irregular, the slope increasing at a short distance from the summit. It is at this level that the loosening of material takes place, either by a disturbance of equilibrium or by earth movements caused by the explosions or by the shock of solid



BARRANCOS OR FURROWS GROOVING THE NORTH FLANK OF THE TERMINAL CONE, FORMED BY DRY AVALANCHES.

(Photograph taken from the Collè Margherita.)

BRECCIA OF THE DRY AVALANCHES ACCUMULATED AT THE FOOT OF A BARRANCO AND ERODED BY A MUD TORRENT.

L'Atrio del Cavallo Covered again by Recent Material.

Ruined Houses at Ottajano.

materials ejected. The material once started advances with accelerated velocity.

The slopes have been deeply furrowed by them, and in places the furrows or "barrancos" possess a great regularity of form, being equally spaced and separated by sharp-edged talus ridges. They serve to explain similar forms of other volcanoes.

The avalanches have built up breccias with a most chaotic structure, identical not only with those of the Antilles, but with trachitic and andesitic breccias of the central massif of France. The furrows have outlined the drainage, and the mud flows have accented and modified their structure. The dry avalanches were not confined to this eruption, but have been noted by observers at many previous eruptions.

Partial destruction of Ottajano and San Giuseppe.—On the night of April 7, at about 12.30 a. m., a shower of lapilli, accompanied by intense electrical phenomena, commenced in the area northeast of the mountain. The fall increased and lasted until 4 a. m. Windows were broken, and the lapilli accumulated on the roofs until these were crushed, killing many who had been unable to flee or those who, as at San Giuseppe, had taken refuge in a church. All the victims, about 200, lost their lives in this way. The lapilli at the time of falling were cold. The quantity of material at Ottajano averaged 7 meters deep: in places it was thicker. The thickness diminished toward the edges of the area and increased toward the mountain. The fine dust which followed the great paroxysm covered the lapilli with a uniform bed several centimeters thick.

The average dimensions of the projectiles ranged from those of a hazelnut to those of a walnut, and some pieces were 15 to 20 centimeters in diameter. They consisted of black or reddish scoria, rather light, but accompanied by angular fragments of denser rocks of various nature, including ancient lavas and metamorphic rocks. The mineralogical and chemical study of this material shows that, apart from a small amount of lapilli resting on the surface and due to the Strombolian explosions, the greatest part of the material has a different composition from that of the recent lava and is the product of the Vulcanian explosions, which have caught up the ancient débris of the volcano. This conclusion conforms with the facts that they arrived cold and that the ejections changed their nature at midnight by becoming completely dark.

The fall at Ottajano, 5 kilometers from the mountain, was greater than at the observatory, only about half that distance. The wind would be unable to transport coarse material to such a distance, and the direction of the ejection instead of being vertical must have been more or less horizontal. The history of Vesuvius shows that eruptions have taken place in greatly inclined or horizontal directions.

and the distribution of the material that buried Pompeii indicates an eruption of this character.

Fall of ash.—This includes all fine products of ejection. In the Strombolian ejections these products are portions of the new magma, thrown out in a more or less fluid condition. They are distorted drops of glass or scoria of minute dimensions, broken and worn by friction. This type has played only a small part at the beginning of an eruption, and the deposits are covered by the products of the Vulcanian explosions, which are composed of fragments of solid rock, broken by the explosions, and have a complex origin and composition. The coarse, ash-like, fine sand which fell at Naples in the night of April 4, was black, and was composed of minute fragments rich in glass, the result of the destruction of the small interior cone. It was therefore formed of the new magma thrown out by Strombolian explosion a short time before the main activity. But the fine dust of the following days resulted from the trituration of old products of eruption and was formed in the process of emptying the crater by Vulcanian explosions. This material, consisting at first of large blocks, lapilli, and small fragments, became gradually finer through the repeated trituration received by falling back into the crater to be reejected.

The rocks thus reduced to fine dust were of varied nature and had undergone metamorphism and decomposition. The composition has not remained constant like that of the Strombolian ejections, being more like that of the scoria of Ottajano than that of the new magma. The following analysis of material collected at the edge of the crater illustrates this point:

SiO_2	48.00	K_2O	5.26
Al_2O_3	16.10	TiO_2	1.02
Fe_2O_3	3.35	P_2O_5	Trace
FeO	4.90	Cl	.49
MgO	6.53	Fire loss	.25
CaO	11.35		
Na_2O	3.04		100.29

The fine ash, through transportation by wind, undergoes a classification according to size of grain and density. It ranges in color from grayish white to rose. The latter tint results from oxidation of the ferruginous minerals, and can be produced after the fall. The same fact was noticeable on Mont Pelée. The ash, at first a dazzling white, became on the following day a reddish tint that deepened rapidly. The white color of the Vesuvian ash, formed from dark rocks, is explained by the fineness of the particles. The slopes covered by this white dust present an aspect of snow fields. The surface of this mobile material was first modeled by the wind like sand dunes; then it began to yield to gravity and absorbed

VOLCANIC ASH ACCUMULATED IN THE STREETS OF OTTAJANO.

A STREET OF OTTAJANO.

SNOWY APPEARANCE OF THE VOLCANO. FINE ASH BLOWN INTO SHAPES BY THE WIND.

FINE ASH, ABRADED BY THE WIND, COVERING THE LAVA FLOW OF 1905-6 IN THE VICINITY OF THE OBSERVATORY.

moisture, and became immobile, and erosion exposed irregular lines of lamination. The action of light rains accompanying or immediately following the fall produced granulation. No granules were observed, however, as large as peas, such as are common in the Antilles and also in ash beds of Pompeii. The conditions most favorable to the production of this structure are fineness of grain and a succession of showers insufficient to soak the material. The first condition is illustrated at Pompeii, where the pisolites are found only in the upper and finest part of a bed. When the precipitation is great at the time of an ash fall, a mud is produced which can unite into small globules before reaching the ground.

The distribution of the ash being determined by the wind is very irregular in the Vesuvian area. On the other hand, in the Tropics, where trade winds prevail, the dissymmetry of these deposits, with reference to their source, is a characteristic feature. The thickness of the deposit ranged from 3 centimeters at Naples to 20 centimeters at the base of the volcano. The portion that reached the higher regions of the atmosphere was transported far beyond the bounds of Italy.

On the flanks of the volcano, and particularly near the crater, the ash has contributed to the formation of dust spouts, flaring above and terminating at the surface in a narrow stem. They had a very rapid gyratory movement and a slow movement laterally.

The fine ash which covered the vegetation seemed at first to destroy all things, but the buds of the vines being still closed the destruction was less than was expected, and at the beginning of May the country was again luxuriantly green. The floating fauna in the Bay of Naples is reported to have suffered much by the eruption and also some of the animal life at the bottom of the bay.

An observation was made—interesting to paleontologists studying problematic organisms—concerning animal trails. At the beginning of the eruption where the ash was light and uncompacted numerous and varied trails were to be seen made by lizards, small snakes, and coleoptera. At the end of the trails made by the last-named, the animal itself could often be found still living or entombed in the ash.

II. Fumaroles and Products of Eruption.

FUMAROLES.

Previous eruptions of Vesuvius have played an important part in the acquisition of definite knowledge regarding volcanic fumaroles.

Fouqué has shown that the chemical composition of a fumarole is essentially a function of its temperature. The fumaroles of high temperature spring only from flowing lava and furnish white sublimates of the alkaline chlorides, associated at times on Vesuvius with

copper oxide (tenorite). These fumaroles are neutral so far as they are really dry. When the temperature permits the appearance of water vapor, they become acid (hydrochloric acid, then sulphurous acid); their sublimates are then colored yellow, red, or green by metallic chlorides and sulphates. Later come the fumaroles with ammonium chloride; then those characterized by deposits of sulphur, with gaseous products rich in hydrogen sulphide; and last of all are the fumaroles containing carburetted hydrogen and carbonic acid.

It is well understood that these divisions are somewhat arbitrarily established and that the products of one type are frequently transformed by the gases of the type that follows. It has apparently been well established by Palmieri that at Vesuvius cuprous chloride of the acid fumaroles results from the attack of the hydrochloric acid of the cooler type upon the tenorite of the dry fumaroles; that hematite once formed can be changed into ferrous chloride; that calcium sulphate, common in the lower types, can form at the expense of the calcium chloride.

Finally, beside the products of sublimation brought from a greater or less depth, are others resulting from the attack upon the walls of the fumaroles by acid vapors. This is common in the fumaroles with chlorides and sulphates in which minerals are formed at a temperature below that demanded by the true sublimates.

Lavas in contact with fumaroles of high temperature are strikingly fresh, whereas the same rocks are profoundly altered when exposed to the same vapors at a temperature low enough to permit the condensation of water vapors.

FUMAROLES OF THE LAVA.

I was unable to observe the dry fumaroles in action, but their trace was found at Boscotrecase as white, green, or yellowish concretions serving as a support for the crystallized ammonium chloride. These concretions contained also a large proportion of the chlorides of potassium and sodium, in some cases with a little iron and aluminum and traces of lead and copper.

The true acid fumaroles, rich in ferrous chloride, are only found toward the source of the flows and, as I shall show farther on, they apparently mark the place from which the lava issued. This is generally true of Vesuvius except in the greatest flows. Hematite, also resulting from the reaction at a high temperature of water vapor upon ferrous chloride, is rarely found in the flows, but is common at their points of emergence and in the crater.

The fumaroles at a temperature below 400° C., with a weak acid reaction, are very abundant in the terminal portions of the flow of May 8. They furnish magnificent geodes containing crystals of ammonium chloride, generally colorless, but in some cases with a

yellowish tint from ferrous chloride or organic products. A notable fact is the presence of fluorine in the salmiac. Only a small amount of water vapor came from the fumaroles, but after each shower abundant vapors of superficial origin were found. These fumaroles became less abundant toward the source, but were numerous in the region where the lava having left the ancient flows covered the cultivated regions. Although a part of the ammonium chloride is of deep origin, it is probable that the slow combustion of organic matter has played some part in its production. The mineral was found to form continuous crusts along the walls of houses in Boscotrecase buried by the lava, in which organic combustion was in progress. A few days after the lava stopped flowing, a road was laid out over the surface. The lava was still warm, and in places the ammonium chloride crystallized between the fragments which formed the road-bed. It was a strange spectacle to see the crowd of people traversing the steaming lava, still incandescent some decimeters from the surface.

Sublimations of sulphur occur in limited quantity at Boscotrecase. It forms small orthorhombic octahedrons, or a melted glaze, at the orifice of the hydrogen sulphide fumaroles, the temperature of which must have been approximately 100°, and at the most slightly above 118° C.

FUMAROLES OF THE FISSURES AND OF THE CRATER.

At the origin of the flows that started from the fissures found at an altitude of 600 meters there were crevasses of greater or less depth, still very warm at the time of my observations. An acid water vapor was being given off, and the edges of the fissures were decorated with chlorides, notably ferrous chloride. These were evidently acid fumaroles of deep origin. The same is true of the more active fumaroles on the slopes below the notch of the crater, their temperature being mostly higher than 400°. The hydrochloric and sulphurous vapors were suffocating, the coating of chloride was much thicker than in the preceding case, and there was a deliquescent mass of chlorides of iron, potassium, magnesium, calcium, etc. There were also crystals of realgar and of sulphur in the cooler parts.

I examined many specimens collected in the vicinity of the cone in July. There are several covered by small cubes of galena, sometimes alone, sometimes resting upon pyrite, or supporting octahedrons of magnetite and lamellæ of hematite. The cubes have often the hopper form, like those created by sublimation in metallurgical operations. It is the first time that lead sulphide has been observed in a fumarole of Mount Vesuvius, and it was doubtless formed by the reaction of hydrogen sulphide upon the chloride of lead, known for a long time in this volcano.

Although it was not possible to make observations upon the dry fumaroles of the crater, I have found in the Vulcanian breccias important material torn from the deep parts of the crater. A large block contains geodes of colorless and limpid or bluish and opalescent potassium chloride (sylvite), cubes of which are often more than 2 centimeters in diameter. In some geodes the sylvite is covered with crystals of sodium chloride. A. Scacchi has shown that the pure chloride of sodium is extremely rare on Vesuvius, and that it is always accompanied by potassium chloride, which is generally predominant. Up to the present time, however, these minerals have been found on Vesuvius only as incrustations, stalactites, and more rarely as small crystals. Never till now have crystals been observed so comparable in size and perfection to those of Stassfurth, which were formed under entirely different conditions. The crystals of sodium chloride do not contain potash; the sylvite contains 2.66 per cent of sodium chloride, existing doubtless as an impurity, because the index of refraction is exactly that for pure sylvite. I have found also crystals of a new mineral, just described by Johnston Lavis—a chloride of potash and manganese with a little soda (chloromanganokalite). There is, further, a small amount of magnesium and calcium chlorides and undetermined sulphates. The block impregnated with these salts is a fresh vesicular leucotephrite, and there is no doubt but that the chlorides were formed by sublimation. A notable quantity of manganese chloride accompanies alkaline chlorides. The great size of the crystals shows they were formed at a high temperature, free from disturbance.

SECONDARY FUMAROLES.

These products emitted by a lava flow are determined by the decreasing temperature of the magma in the course of cooling, and are constituents of the fluid magma at the time of its ejection.

If a limited portion of magma is violently expelled instead of being quietly poured out, it cools quickly and loses at once all the volatile products which do not remain imprisoned. Under conditions of slow cooling, however, fragmental lava may behave like the continuous rock of a flow, the nature of the products of emanation being limited only by the temperature at the time of ejection. Breccias accumulated in a short time, like those of Mount Pelée, offer the best conditions for the slow cooling of a new magma transported to a distance. They were formed of coarse and fine material of poor conductivity for heat, and contained some blocks of high temperature. The release of volatile products, slow and tranquil when the cooling of the breccia was undisturbed, rapid and violent when it was hastened by rain water, determined the production of fumaroles, first

BLOCK CONTAINING LARGE CRYSTALS OF SYLVITE EJECTED BY A VULCANIAN EXPLOSION.

BARRANCOS OR FURROWS OF THE TERMINAL CONE SERVING AS CHANNELS FOR THE RAIN WATER.

scattered generally over the surface and then localized at certain points. I designate these fumaroles, of superficial origin, as secondary fumaroles.

The production of breccias in this eruption of Vesuvius, built up in the dry way, seemed to offer favorable conditions for their formation, but in no case was the temperature sufficiently high to produce true secondary fumaroles. This resulted from their origin: they were not formed from the new magma, but from the débris of the crater. The abundance of alkaline chlorides contained in the blocks of the breccia indicates that if the temperature had been favorable, products of secondary fumaroles would have been abundant.

EXHALATIONS.

The end of the great eruptions of Vesuvius is generally signalized by the release of much carbonic acid and other exhalations, which become specially abundant in the lower parts of the mountain in caves, wells, and quarries. These are sometimes of fatal effect, and ordinarily are injurious to vegetation. They made their appearance at the end of the eruption, but not till I had left Italy. The presence of asphyxiating gases during the eruption was noted at the observatory, which at one time was invaded by them.

OTHER PHENOMENA.

EARTH MOVEMENTS.

Throughout the eruption violent earth movements shook the cone, and were felt at times through much of the Vesuvian region. They were particularly violent during the night of April 7, the seismological instruments at the observatory being greatly agitated throughout this period. These movements decreased gradually toward the end of April and it is very probable, as in the case of Mont Pelée, that vibrations of the atmosphere caused by the great explosions have played some part in the destruction of buildings. The observations of Baratta and Mercalli show that a temporary elevation of the coast was produced between Portici and Vico Equense.

ELECTRIC PHENOMENA.

The columns of vapor and solid material ejected by the Vulcanian explosions produced electric phenomena of great intensity. They began on April 4, and were especially developed in the night of April 8, but decreased gradually from that time, though they were notable up to the 13th. G. di Paola describes the splendid sight which they presented. The enormous columns, rising from the crater with a

deafening sound, were a network of incessant lightnings, some straight, some zigzag, and some in the form of tremendous arcs prolonged from the summit of Monte Somma to that of Vesuvius. The observations of Paola confirm those of Palmieri. The electric potential of the ash that falls is always negative, whereas that of the water vapor on the way to condensation, which rises, is positive. The production of lightning in the vapor emitted from the crater implies a rapid ascent; that is to say, a great violence of explosion and abundant solid material. This is why the electric phenomena cease with the paroxysmal period, although the density of the clouds remains great for days.

THE MUD TORRENTS.

The customary epilogue of the volcanic eruptions of Vesuvius consists in the formation of mud torrents, the "lave d'aqua" and "lave di fango" of this volcano being celebrated. The recent eruption has furnished much material for detailed study by the localization of the ejected products—thick beds of lapilli in the northeast sector, the breccia with coarse constituents formed in the dry way upon the cone and carried down by avalanches, and the fine dust scattered everywhere on the volcano.

The mechanism of the production of mud torrents in the course of an eruption is not complicated. The loose material freshly ejected, always more or less porous, absorbs the rain water from the showers of the upper slopes. If these are very intense, as was the case in the Antilles, a torrent can form immediately; but on Vesuvius, in the first days of the eruption, the rainfall was localized, intermittent, and slight, and imbibition took place gradually. When it had proceeded sufficiently far, the entire mass commenced to move upon the slopes as a thick mud, which advanced rapidly down the valleys, eroding and transporting much material. The mud lava finally ceased to flow and by its consolidation formed a conglomerate with a chaotic structure. The most simple case is realized when the quantity of rain is not great, but if the rainfall continues there comes a more liquid flood, which erodes the mud that has gone before, cuts into the underlying material, and deposits on the lower parts of the mountain sediments with torrential stratification.

The mud lava on the northeast side of the mountain consisted of rather even-grained lapilli united by fine mud. The flow occupying the bed of the torrent of Ottajano, on becoming dry, formed a black mass 8 meters wide by 0.75 meter thick at the front end. The surface was covered with concentric wrinkles like those of viscous lava and longitudinal furrows, indicating the different levels of the stream. It bore a remarkable resemblance to true lava flows. On drying, the

surface became covered with a white coating of alkaline chlorides and sulphates that impregnated all the erupted products. Some days later, on account of the persistent rains, the erosive period was inaugurated, with its disastrous floods.

The phenomena that I have seen in the production and intermixture of the chaotic formations, accumulated in the dry way by avalanches, with those produced at their expense under the influence of water, and the analogy of structure presented by them after drying and settling, are of great importance for geologists who have to decipher the structure of extinct volcanoes, like those of Auvergne. They explain the difficulties of interpretation, often inexplicable, that one encounters in the study of breccias and conglomerates of trachytic and andesitic origin.

THE PRODUCTS OF ERUPTION.

The massif of Vesuvius, comprising Monte Somma and Vesuvius, presents great variations from the petrographic viewpoint, but all the rocks have a family likeness. They are all very potassic and either contain leucite or have a composition potentially leucitic.

The petrographic character of Monte Somma is more complex than that of Vesuvius, because it contains not only basic rocks with leucite and the leucotephrites, which form dikes and flows, but also types of white acid rocks, which form thick beds of tuffs and breccias. Vesuvius, on the other hand, has been built up by an accumulation of scoriae, ashes, flows, and dikes, belonging only to leucotephrites, which, according to the eruptions, present further variations still imperfectly studied. There are different facies depending upon the greater or less abundance of phenocrysts of the predominant minerals—leucite, augite, olivine.

I shall take up successively the new magma thrown out as Strombolian explosions and poured out as flows, and then the old débris, which constitutes the predominant material expelled by the Vulcanian explosions.

NEW MAGMA.

The lava has a grayish-black ground mass, with rather abundant phenocrysts of leucite and augite some millimeters in diameter. It was particularly interesting to determine if, in the course of the eruption, there was any chemical change resulting from differentiation between the upper part of the magma, as exhibited in the Strombolian explosions at the beginning of the eruption, and the portion poured out last of all. The following analyses show there has been no systematic variation and that the magma has kept a remarkably

uniform composition. Analyses of more numerous examples would show perhaps greater differences.

	A.	B.	C.	D.
SiO_2	47.50	48.28	47.71	47.65
Al_2O_3	18.59	18.39	18.44	19.28
Fe_2O_3	1.52	1.12	2.46	2.63
FeO	7.62	7.88	5.68	6.48
MgO	3.86	3.72	4.80	4.19
CaO	9.16	9.20	9.42	9.01
Na_2O	2.72	2.84	2.75	2.78
K_2O	7.05	7.25	7.64	7.47
TiO_2	1.05	1.28	.37	Trace
P_2O_5	Trace	.51	....	.50
Fire loss	1.25	.62	....	.24
	100.32	101.09	99.27	100.23

A. Scoria ejected at beginning of the eruption collected by Matteucci near the observatory.
B. Lava of April 8 collected near the cemetery of Torre Annunziata.
C. Lava of 1631. Analysis by Washington.
D. Lava of 1872. Analysis by Washington.

This composition is characteristic of the Vesuvian lavas, and is particularly remarkable for the high percentage of potassium. These rocks belong to the type Vesuvose (II 8. 2. 2) of the quantitative classification, and the older rocks of Somma differ from the recent lavas by less potash and a smaller ratio of $K_2O:Na_2O$.

I have followed the development of crystallization by comparing forms of cooling less and less rapid. The scoriæ of the Strombolian explosions are very rich in brown glass, the specimen analyzed being fragile and crumbling easily under pressure of the finger. Another specimen collected at the fissure of 1,200 meters altitude is, on the contrary, very resistant. The scoriæ contain in their glass large crystals of augite, leucite, titanomagnetite, a small proportion of basic plagioclase, with a little apatite and olivine. There are few or no microlites of feldspar, but those of augite are abundant. The normal and tranquil process of crystallization was interrupted, and cooling was so rapid that crystals were not developed.

A form of consolidation less rapid is observable on the front and upon the superficial parts of the flows. The rock still contains much brown glass and it contains the same phenocrysts as the scoriæ, but they appear more abundant, and biotite is not as rare as a phenocryst. There is also a large amount of microlitic leucite, augite, and plagioclase.

The most crystalline type is found in the interior of large blocks broken by contraction from the surface of the flows. The rock,

although of fine grain, is almost holocrystalline by a more or less complete devitrification and larger development of the microlites. The glass inclusions of the leucite are often transformed into augite and titanomagnetite.

From these observations it may be concluded that a part, at least, of the phenocrysts of leucite are of intratelluric origin, but not of great depth, because the lava poured out rapidly contains fewer of them that the scoriæ thrown from the crater; furthermore, the microlitic period of the leucite did not begin till the ejection.

THE PRODUCTS OF THE VULCANIAN EXPLOSIONS.

The most important of these products are those that have covered the cone and furnished the material for the dry avalanches. They include the fine dust above described, the lapilli that fell at Ottajano, and the material of the dry breccias.

Lapilli.—The greatest part of the lapilli is formed of black scoriaceous material, either light with a glazed surface or heavy with a tarnished surface, often reddish. They are distinguishable from the material of the Strombolian explosions by large crystals of augite and lamellæ of biotite. Microscopic examination shows, further, a few phenocrysts of leucite, plagioclase, apatite, and olivine, embedded in a ground mass composed of augite needles, minute crystals of leucite, and grains of magnetite. The chemical analysis of these scoriæ has given the following results, showing that they belong to a type altogether different from that of the new lava in being less aluminous, poorer in alkalies, but containing more magnesian and more calcic:

SiO_2	48.10	K_2O	4.22
Al_2O_3	15.31	TiO_2	1.15
Fe_2O_3	3.20	P_2O_5	.12
FeO	5.45	Fire loss	.87
MgO	7.55		
CaO	12.45		100.25
Na_2O	1.98		

The mineralogical and chemical study of these scoriæ confirms what has been already said regarding their origin—that they have not been derived from the new magma, but have been torn away from the older rocks of the cone by the Vulcanian explosions.

The lapilli are mixed with numerous fragments of nonscoriaceous rocks, described below.

Breccias.—The materials thrown upon the mountain slopes permit of making an inventory of the rocks entering into the construction of the cone of Vesuvius and its foundations and of studying the

conditions of metamorphism which prevail at the depths from which a part of the material has been derived.

These rocks can be referred to two groups: First, those of volcanic origin, and second, limestone and its metamorphic derivatives, which, while important from the metamorphic standpoint, furnish no information other than that already available from the study of the tuffs of Monte Somma.

The blocks of volcanic origin include fragments of rocks, in places broken and ejected by the explosions (these were already consolidated, but of a high temperature), and also fragments that had seen the light one or more times as old products of ejection, torn from beds of tuff or from breccias of former eruptions. All are leucotephrites, but vary in chemical and mineralogical composition and in texture. Some of them are of types comparable to those thrown out in the historic flows of Vesuvius; others, much more crystalline with a doleritic texture, are like types prevailing in the tuffs and breccias of Monte Somma, being fragments of intrusive flows or dikes crystallized at considerable depth under different conditions than the preceding types.

The study of these different rocks permits of tracing the variations of the magma of this volcanic massif and the influence of the conditions of cooling upon the nature of the rocks derived from it; but the metamorphic modifications observed in many of them have a more general importance.

These modifications are of two kinds. The one kind is due only to the action of heat and is produced in blocks carried up by the fluid magma or falling into it after ejection. These changes can be of recent origin and be accomplished in the course of the eruption. The fusible minerals are melted, forming a glass enveloping the other constituents and frequently containing new minerals.

Much more important are the other modifications, which have been produced at a temperature below the melting point of the most fusible of the constituents. They are not the work of the recent eruption, but have resulted from a previous long-continued process. The intensity of the modification is variable, though in some specimens the microscopic appearance is not changed. A specimen originally vesicular or scoriaceous, has its cavities lined with newly formed crystals; in the case of a breccia the fragments become coated with new minerals. The attack is often more profound, crystals of leucite becoming by corrosion like small geodes, the cavities enlarge, the texture changes, the rock becomes porous and very crystalline, and large crystals, particularly microsommite, appear simulating phenocrysts.

The essential character of all these modifications is the partial or entire disappearance of leucite, which maintains its geometric form, but becomes transformed into sanidine, sodalite, and especially microsommite, frequently accompanied by basic plagioclase. The formation of new minerals does not take place necessarily in the places occupied by the old minerals, but may proceed in adjacent cavities. These colorless minerals, feldspars and feldspathoids, are accompanied by numerous other minerals such as augite, hornblende, biotite, hematite, magnetite, and more rarely melanite, sphene, and olivine; in some cases I have observed recrystallization of leucite. These minerals present definite associations depending upon the character of the rock at the expense of which they are formed, and on the conditions governing their formation. The brown hornblende, for example, and its associate, magnetite, appear to be formed in a reducing medium, whereas aegirite-augite, always accompanied by abundant crystals of hematite, has crystallized in an oxydizing medium.

The new minerals are not only found as beautiful crystals in druses; they also impregnate the rock, inclosing the normal minerals. The augite and amphibole and at times the mica may become oriented upon the original pyroxene. This is especially true of the augite. The primary augite becomes colored progressively yellow and takes on the optical properties of aegirite-augite.

The mechanism of these transformations can be established with a certain probability. We know that the eruptive period terminated by the recent disaster has had as a principal result the filling of the crater formed by the eruption of 1872. The frequent flows from the flanks of Vesuvius since 1875 show that melted magma has been for this whole period in intimate contact with the walls of the subterranean channels. It has raised their temperature above 500° C. and furnished them with emanations, the nature of which we know. The transformations, which are to be attributed to these emanations, have been produced by the chlorides and alkaline sulphates, especially by those of sodium that impregnate all the samples studied. It is striking to note the constant substitution of sodic or calic minerals for leucite. The two most common acid minerals are sodalite and microsommite.

The general interest that these transformations present is, then, to show with perfect clearness the influence in contact metamorphism of volatile products emanating from a magma, and the fixation of some of them by the transformed rock.

The leucitic magmas occupy a special place among eruptives by the intensity of the contact metamorphism they exhibit. I have shown in other instances by consideration of their inclusions, that they are

comparable in their effects to trachytic and granitic magmas. The instability of leucite in the presence of fumaroles, gives a better comprehension of the reasons why this mineral is so rare in plutonic rocks, and for its constant transformation (into orthoclase or into orthoclase and nephelite) in some granular rocks (syenites with pseudoleucite) where it can crystallize under special conditions, but can not maintain itself.

Conclusions.

Knowing the different phenomena that have successively taken place in the eruption of 1906, it is in order to consider the place occupied by this eruption among the preceding eruptions of Vesuvius. This investigation is facilitated by an interesting note by Mercalli on the succession of eruptive phenomena of this volcano.

Precise observations date from the great eruption of 1631, and since that time the activity has been almost continuous. The nine eruptions noted in the course of the fifteen centuries that followed the Phinian outburst furnish us with but meager information.

The eruptions are divisible into two groups—those exclusively explosive and those in which explosions have been accompanied by ejections of lava.

The eruptions exclusively explosive occur ordinarily after periods of repose. They begin by small Vulcanian explosions, followed soon by a Strombolian explosion accompanied by violent detonations, and terminate by Vulcanian explosions more or less violent, launching into space a great quantity of fine ash. The eruptions of A. D. 79, of 472 (in which ash is reported to have been transported as far as Constantinople), those of 1649 to 1660, of May, September, and December, 1900, and of March and April, 1903, are examples.

The eruptions that have produced lavas are also divisible into two groups—those in which lava starts from the flanks of the cone (lateral eruptions) and those in which the point of outflow is exterior to the cone (eccentric eruptions).

The lateral eruptions are most frequent, and they begin almost always in the same manner. Strombolian explosions fill the crater of the preceding eruption, building there a small terminal cone; the melted magma mounts high, fills the space between the cone and the edges of the old crater, and often pours over upon the slopes of the main cone; fumaroles appear above and a fissure is formed; explosions destroy the terminal cone; earth movements shake the mountain, and the Strombolian explosions diminish or cease; a fissure opens high in the cone, lava flows from it for a day or two; then another opening appears at a lower level.

From this time the eruption may develop in either of two ways. In the most frequent case, which may be characterized with Mercalli as the type of 1895, the flow is tranquil and prolonged for several months. At the beginning the crater deepens and Vulcanian explosions take place, but as the lava flows away Strombolian or mixed explosions succeed, increasing in intensity as the flow ceases. The eruptions of October, 1751; April, 1766; August, 1834; May, 1859; December, 1881; June, 1891; July, 1895; and August, 1903, are examples.

In the second type, that of 1872, the outflow is violent and rapid and lasts only a day or a few hours. The maximum activity immediately precedes or is contemporaneous with the outflow of lava. Explosive phenomena take place at times also at the lateral fissure. The crater enlarges by the explosions, the summit sinks, and at the end of the eruption the mountain, with diminished height, has a wide, deep crater. The eruptions of 1631, 1737, 1767, 1779, 1822, 1839, 1850, 1855, 1868, and 1872 are examples.

The eccentric eruptions (type of 1760), which are the rule on Etna, are rare on Vesuvius (1760, 1794, 1861). The lava then comes from adventitious cones that form on the southeast slope of Monte Somma at altitudes from 500 to 300 meters.

The eruptions of the types of 1872 and 1760 always close a period of activity and are invariably followed by a period of repose. The recent eruption belongs to the type of 1872 and closes the period of activity almost continuous since 1875. It presents the dominant characteristics of the type—a rapid and short flow of lava from the flanks; violent Vulcanian explosions, destroying the summit and forming a caldera; and complete cessation of activity. No new phenomena have been noted in the course of this eruption; the flow is comparable to that of 1872, but the intensity of explosion has been greater and more like those of 1779 and 1822.

The results of the study of the dry avalanches, the mechanism of their production, their action upon the topography of the cone, the breccias that they have formed, and the facts regarding metamorphism furnished by the blocks ejected by the Vulcanian explosions, constitute, in my opinion, the principal acquisitions that science owes to the eruption.

It is particularly suggestive to see opposed characteristics reunited in the same eruption and realized successively with equal intensity. Vesuvius has acted at first under the form common to basic magmas and then under that regarded as characteristic of acid magmas. It has furnished Strombolian ejections of incandescent lava and long and rapid flows like those of basalt, and finally, by the Vulcanian

explosions of material completely solidified, has accumulated breccias identical in structure with those of rhyolites, trachytes, and acid andesites. It has, then, reproduced in a few days the secular history of Mont Pelée, and brought another argument in support of the idea mentioned at the beginning of this paper—that the form of dynamism is essentially a function of the physical condition of the magma at the beginning of the eruption, and the recent eruption has further shown how easily the form of dynamism changes with this essential condition.

In conclusion, this eruption throws a definite light upon that which destroyed Pompeii in the year 79, and the explosive part of it is undoubtedly the reproduction of that described by Pliny. The disaster at Ottajano and San Giuseppe is, then, the repetition on a small scale of the destruction of Pompeii, but with this difference—that the pumice of 79 is constituted very probably not of ancient débris like the scoriæ of 1906, but of new magma.

TO THE NORTH MAGNETIC POLE AND THROUGH THE NORTHWEST PASSAGE.[a]

By Capt. Roald Amundsen.

To Sir John Franklin must be given the honor of having discovered the Northwest Passage, and to Admiral Sir Robert McClure that of being the first to pass through it, partly in his vessel, the *Investigator*, and partly on foot. On the foundations laid by the splendid work done and the rich fund of experience gained by English navigators in these regions I succeeded—in the track of Sir James Ross, Dr. John Rae, Admiral Sir Leopold M'Clintock, Sir Allen Young, and many others—in making my way in the *Gjöa* to the region around the earth's north magnetic pole, and, furthermore, in sailing through the Northwest Passage in its entirety. If I have thus been the first to sail through the Northwest Passage, it is with pleasure that I share the honor with those brave English seamen—the seamen who here, as in most of the other parts of the world, have taken the lead and shown us the way.

It was the Norwegian minister to England, Dr. Fridtjof Nansen, who, by his great experience and his many good counsels, made the *Gjöa* expedition what it was—one in all respects well planned and excellently equipped. In order not to tire my hearers I will give in as few words as possible the earlier history of the expedition.

The scheme of the *Gjöa* expedition I had a welcome opportunity of laying before the Norwegian Geographical Society on November 25, 1901. It was briefly as follows: With a small vessel and a few companions, to penetrate into the regions around the earth's north magnetic pole, and by a series of accurate observations, extending over a period of two years, to relocate the pole observed by Sir James Ross in 1831 and also to make investigations in its immediate vicinity. This was the chief object of the expedition.

The condition of the ice still farther west allowing, it was furthermore my intention to attempt to sail through the Northwest Passage in its entire extent, this being a problem which for centuries

[a] Read at the Royal Geographical Society, February 11, 1907. Reprinted by permission from The Geographical Journal, London, Vol. XXIX, May, 1907.

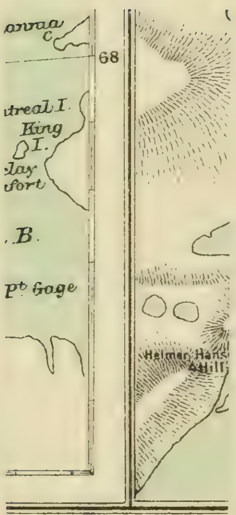
had defied the most persistent efforts. I chose a small vessel, with the view of being better able to pass through the sounds of these regions, which are narrow, shallow, and generally packed with ice. In preferring a small number of members to a larger party, it was—apart from want of space—because, in the event of such a misfortune occurring to us as the loss of our vessel, it would be easier to find means of subsistence for a small than for a greater number of men.

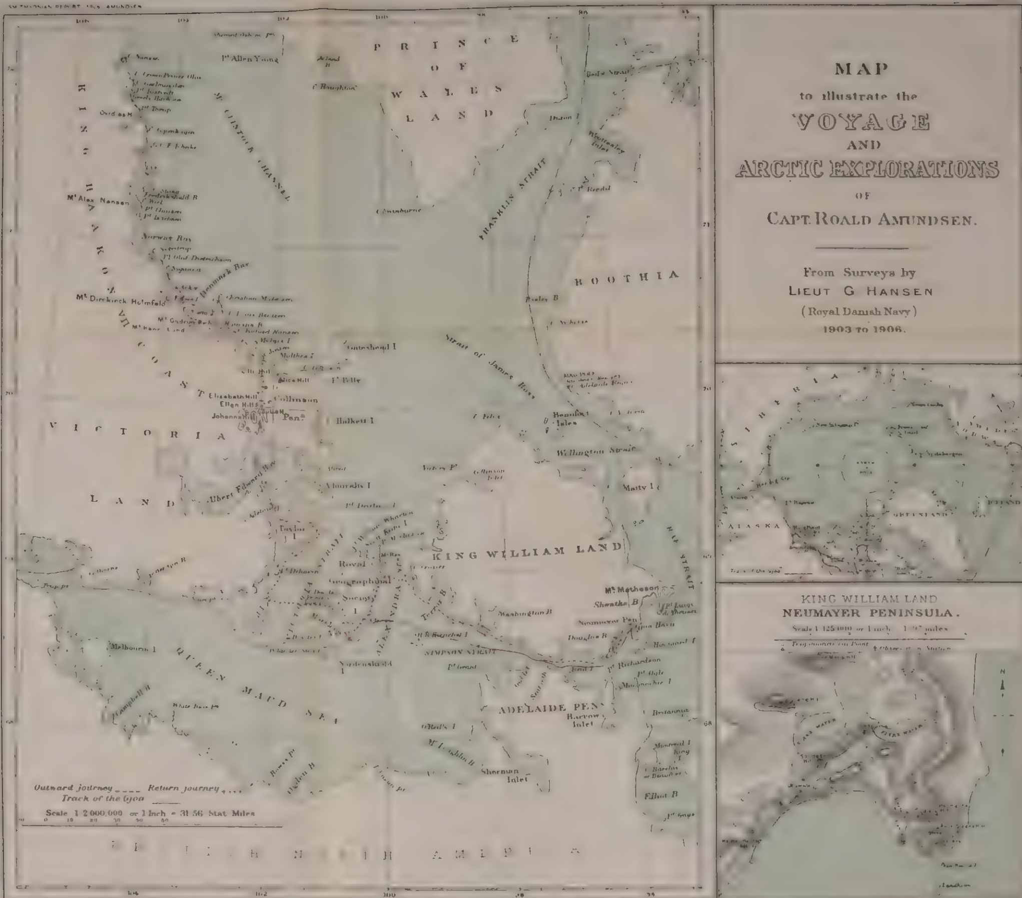
My undertaking, as soon as it became known, awakened great interest in very wide circles, and several wealthy men came forward and supported the enterprise with donations. It would take too long to name all the persons who gave the expedition pecuniary support, but I must in respectful gratitude mention the names of their Majesties King Haakon and King Oscar II.

The vessel of the *Gjöa* expedition was built in Hardanger in 1872, and was the only vessel assigned to the trip. She had originally been used in the herring fisheries along the Norwegian coast; later she was sent to Tromsö, whence she sailed for many years in the arctic sealing trade. She had weathered many a storm, though not always scathless. After my purchase of her I had a small petroleum motor, of 39 indicated horsepower, put into her, to help us along in calm weather. The ice sheathing, which before only reached a couple of planks under the water line, I had lengthened right down to the keel; stout crossbeams were put into the hold and connected with massive joints to the deck and keelson, and the old hempen rigging was replaced by wire rigging.

I had chosen my companions by degrees. First in order I must mention the man who sacrificed his life in the service of the expedition, Gustav Juel Wiik. He was born in 1878, at Horten, and thus lived to be somewhat over 27 years of age. From six weeks' study shortly before the departure of the expedition, at the Magnetic Observatory at Potsdam, where he particularly studied the use of self-registering magnetic instruments, he returned with the most excellent testimonials for industry and thoroughness. I had a good opportunity of seeing, during our three years of work together, that these testimonials were not exaggerated, and the magnetic data we brought back with us I owe, in the first instance, to this young man's painstaking and accurate labor. In addition to his position as assistant in the meteorological observations, he was also the second engineer.

The second in command of the expedition was Lieut. Godfred Hansen, of the Danish navy, born in Copenhagen in 1875. His light-hearted disposition was of absolute benefit to us, and during the three years—more than three years—that he and I spent together in the little cabin of the *Gjöa*, 6 by 9 feet, I became more and more attached to him. It was prophesied before our departure from Norway that


C.
68
treal I.
King
I.
Pt Gage
Helmer Hans
Hill


MAP
to illustrate the
VOYAGE
AND
ARCTIC EXPLORATIONS
OF
CAPT. ROALD AMUNDSEN.
From Surveys by
LIEUT G HANSEN
(Royal Danish Navy)
1903 to 1906.
PRINCE OF WALES LAND
BOOTHIA
VICTORIA LAND
KING WILLIAM LAND
ADELAIDE PEN.
QUEEN MAUD SEA
FRANKLIN STRAIT
Strait of James Ross
Wellington Strait
SIMPSON STRAIT
Collinson Pen.
Royal Geographical Society I
Mt. Alex Nansen
Mt. Matheson
Outward journey Return journey
Track of the Gjoa
Scale 1:2 000 000 or 1 Inch = 31.56 Stat. Miles
ALASKA
GREENLAND
KING WILLIAM LAND
NEUMAYER PENINSULA.

within a year we should not be able to bear the sight of one another. This prophecy, however, we thoroughly gave the lie to, and I almost think we could have managed three years more. He was the navigator of the expedition, the astronomer, geologist, surgeon, photographer, electrician, and an expert in dealing with our explosives. He also played star parts as meteorologist and magnetician. Sergt. Peder Ristvedt was born in Sandsvär in 1873. Besides being first engineer, he was also our meteorologist, smith, clockmaker, copper and tin smith, gunsmith, etc. I knew Ristvedt before I engaged him, as he had taken part as assistant in my first expedition in the *Gjöa*, in 1901. I was thus aware of what I was doing when I secured the services of this capable man and pleasant companion. Anton Lund was the first mate of the expedition. He was born at Tromsö in 1864, and was thus the oldest member of the expedition. He had sailed from his earliest youth on our Norwegian sloops to the Arctic Ocean, and was consequently an unusually experienced man in all matters connected with the condition of the ice and navigation through it. Helmer Hansen was born in the Vesteraal Islands in 1870. He had previously been a peasant, fisherman, and arctic navigator. His position was that of second mate, and he was careful and conscientious in all that he did. Last of all, then, comes the cook, Adolf Henrik Lindström, born at Hammerfest in 1865. He took part in Sverdrup's expedition in the *Fram*, and had thus extensive experience as an arctic cook. I will confine myself to informing you that, besides providing us for three years with excellently prepared food, served to the minute, he voluntarily filled the vacant posts of botanist and zoologist. His kitchen work ended, he was pretty sure to be seen abroad on arctic summer evenings with his botanical collecting box, his shotgun, and his butterfly net, and woe to the flower, bird or insect which came his way! After this description of my comrades, I feel sure that none of my hearers will be surprised that we succeeded in accomplishing what we did.

At 12 o'clock on the night between June 16 and 17, 1903, we cast off, and the *Gjöa* was towed down the Christiania Fiord. It poured with rain and was as dark as in a sack. Some of my friends tried to console me by saying that the weather was much the same when Nansen started in 1893, and that it was a good omen. However, I had never been a believer in omens, and I therefore felt myself, in spite of these auspicious torrents, very uncomfortable in my soaking clothes. At 6 in the morning we entered the harbor at Horten, where we took our explosives aboard. At 11 in the forenoon the last tie which bound us to home was broken, for the tow rope snapped and left the *Gjöa* to her own fate. We were then just outside Färder light-house. After the tug had shown us the proper farewell civilities, it stood up the fiord again and the *Gjöa*, by her own exertions.

worked her way slowly forward against a southerly breeze. The voyage across the Atlantic has been made countless times, and does not offer any particular interest. A great number of people had, indeed, designated this ocean as the *Gjöa's* last resting place; but in spite of many prophecies and many warnings our good little *Gjöa* quietly and calmly worked her way onward, giving not a moment's thought to all the wiseacres. How glorious it was to have exchanged the narrow hot streets for the open sea, and not only we human beings enjoyed the change, but our dogs likewise. We had, I should explain, six dogs with us which had taken part in Sverdrup's expedition, and they seemed to enjoy the voyage exceedingly, running about and getting into as much mischief as they could. Their spirits were particularly high on rough days, for then they had an agreeable change in their otherwise somewhat monotonous diet (consisting of a stockfish and a quart of water) in the shape of the delicious viands sacrificed to them by my seasick companions.

On July 9 we sighted the first ice, in the vicinity of Cape Farewell, the southern extremity of Greenland, and on the 11th the land around the cape itself appeared in sight. The wind, which had not been particularly favorable to us up to this, did not improve now, and our voyage up the whole of the west coast of Greenland was thus one single struggle against the ever-prevailing north wind. We had to console ourselves with the proverb that it is "an ill winde that bloweth no man to good." Though the opposing wind from the north hindered our progress, it at any rate set the ice in motion southward, and made a way for us.

The voyage, which had hitherto been somewhat monotonous, became more lively on the appearance of the ice. Icebergs of varying shape glided past us and arrested our attention. Now and then we made an excursion into the drift ice and shot some of the beautiful large bladder-nose seal that were lying about on the higher parts of the ice. Both men and dogs were longing for fresh meat, and this seal flesh provided us with an agreeable change in our menu.

On July 24 we sighted Disco Island, and the day afterwards anchored at Godhavn, whither the Royal Danish Greenland Trading Company had been kind enough to bring some of our equipment in their ships. Here we spent five days, enjoying the great hospitality of the inspector and the governor of the colony. After having taken a series of magnetic and astronomical observations and shipped all our things, we left the place on July 31.

On August 8 we reached Holm Island, which marks the beginning of the redoubtable Melville Bay. The ice was packed close, though it proved to be broken. We kept cruising backward and forward alongside the edge, watching for an opportunity to enter it, and at last, on the evening of the 10th, it so far separated that we were able

CAPTAIN ROALD AMUNDSEN.

to slip in. In thick fog we wound our way about through fairly penetrable ice, a few icebergs now and then breaking up the dense masses of the fog with the strength of their flashes, calling to us their own warning. On August 13, at half past 2 in the morning, we saw the last of this fog, the *Gjöa* quietly and calmly gliding out of the thick masses, which had surrounded us as in a nightmare for several days, into a new world, lighted up by the loveliest sunshine and with a marvelously beautiful view. In the east we saw the head of Mellville Bay filled with impenetrable ice fields; to the north lay the fine mountain scenery around Cape York beckoning and calling to us in the sunshine (the feeling was overwhelming!); before us, shining in blue and white, lay the huge masses of drift ice. There was not much open water to be seen from the masthead, but then we did not want very much. On August 15 we reached Dalrymple rock, where two Scotch captains, Milne and Adams, had left a largish depot for us. Here we fell in with the Danish Literary Greenland expedition, and spent a few lively and pleasant hours with the members of it. On August 17 we continued our voyage, and bore across Baffin Bay, in sight of the Carey Islands. It was lucky for us that we met with calm weather here, for with our deeply laden vessel a storm might have had serious consequences. Besides our sky-scraping deck cargo, there were to add to its burden our 18 dogs, the greater number of which had been shipped at Godhavn. By way of making the time go quicker, they had divided themselves into two about equally strong sides, and from time to time made inroads on each other's territory. This game, needless to say, was hardly to the liking of the man who happened to have the watch, and many a round oath found its way out into the world. On August 20 we stood into Lancaster Sound. A few icebergs which had collected around Cape Horsburgh and some slack ice stretched straight across the sound. We kept in under the northern shore. The land made an exceedingly barren impression; there was no vegetation to be seen, and the mountains were high and table-topped. It was, however, not often that we were able to see land, the fog for the most part being thick and heavy.

On August 22 we reached Beechey Island, where I had arranged to stop and take a series of magnetic observations which were to decide our future course. Before the departure of the expedition several persons more interested than learned in terrestrial magnetism had written to me, pretending by a subtle method, which, however, they did not disclose, to have discovered that the magnetic pole had moved, with a speed of I don't know how many miles in the year, in a northwesterly direction, and was now on Prince Patrick Land. They might as well have said in the moon for all they knew.

Beechey Island gives a barren and dismal impression, and particularly sad are the ruins of the house erected by the British Government

for the succor of the Franklin expedition. Five graves did not make it any more cheerful. The memorial stone to Sir John Franklin was the only thing which in the least brightened all this sadness—a handsome marble tablet put up to his memory by his faithful wife.

The magnetic observations indicated the pole as being in a southerly direction, and Prince Patrick Land was this time left in peace. We left Beechey Island on the 24th and shaped the course for Peel Sound, entering those waters in dense fog. The ice was the whole time fairly penetrable, and we met only loose streams, which presented no hindrance. At Prescot Island the compass, which for some time had been somewhat sluggish, entirely refused to act, and we could as well have used a stick to steer by. Navigation as we now practiced it was at first a somewhat unfamiliar proceeding, and when one watch released the other and the fog lay close and compact, as it always did, strange remarks might have been heard. "What are you steering?" would ask the relieving watch in a cross and sleepy tone. "Supposed to be steering south, but ain't sure we're not going north;" and as he handed the tiller to the other, one would hear, "Steady—so." So there one would be at 2 o'clock in the morning, just up from a comfortable, warm berth, the fog pouring down over everything, and absolutely nothing to be seen in any direction, and one was to steer steady. This was certainly great fun; but custom is a remarkable thing. Within a short time we became quite at home even with this sort of navigation, and we made way. On August 28 we passed the spot where Sir Allen Young was stopped in his vesel, the *Pandora*, by impenetrable ice. Later in the forenoon the western entrance to Bellot Strait, where Sir Leopold M'Clintock in vain tried to get through, was passed. Now began our voyage along the west coast of Boothia Felix—a voyage that more than once looked dark for us. We were not hindered by ice to any great extent; the land lead was, as a rule, so wide that we could get along without difficulty; but what impeded us most was the shoal water, the constant fog, and the pitch-dark nights. On August 31 we struck ground for the first time. The weather, however, was fine, and we got off without injury. In the evening we anchored off a low island to wait for daybreak, for I no longer dared to go on, now that the nights were so dark, and in such foul waters. How peaceful everything was that evening. It was an unusually dark night and absolutely calm, and what greatly increased our already romantic position was the fact that we—I confess it openly and without shame—had no idea where we were. The land had been mapped in winter, and many of the small islands which we came across were not marked at all, the snow covering them at the time having rendered them invisible. All was so peaceful, quiet and calm. We had all retired and left the watch to one of the engineers whose turn it happened to be.

I had just got out my log to enter the events of the day, when I was suddenly interrupted by the cry of fire. I knew what this meant on board a small vessel carrying 7,000 gallons of petroleum, great quantities of gunpowder and explosives, and whose whole hull was, besides, saturated with tar. We were all up on deck in less time than it takes to tell it. The first thing that met our eyes was an enormous pillar of fire rising up through the engine-room skylight. Things didn't look peaceful any longer. We all ran like mad for vessel and life. The engineer on watch had not left his post; he was holding out bravely down below in the suffocating smoke, trying to the best of his abilities to subdue the fire, which had arisen in some cotton permeated with petroleum. This was Wiik. We succeeded by united exertions in becoming master of the fire, and got off without much damage.

The evening of this same day we beat up under an islet and anchored there. We took this to be one of the small islands lying north of Malty Island. It was then blowing hard and night coming on. At 4 the next morning we weighed, and continued our course. It was a fine morning, partially clear, and with a westerly breeze. I was at the tiller and my two comrades were hoisting the sails. Suddenly there was a shock, and we struck three times. All expedients to get off were in vain, and there we were for thirty hours. A strong breeze blew up from the north and came to our assistance, and under crowded sail we succeeded in forcing the *Gjöa* across a 200-yard-long bank and out into comparatively deep water. We lost only our false keel, but from that day to this it has been a matter of wonder to me that human handiwork could have withstood the treatment which the *Gjöa* underwent on that occasion.

During this enforced delay we got a determination for position, and thus knew where we were. About midday we cast anchor off Cape Christian Frederik, on Boothia Felix, so as to get things a little in order after grounding. The wind was then slack and offshore. At 11 in the evening it suddenly went over to the southeast and blew hard. There was no question, in the darkness and the shoal and foul sea outside, of getting underway. There was only one thing to be done, and that was to pay out our cables to the bitter end and await results. The wind soon increased to a gale; the seas were high and short, shaking our chain cables violently. The land did not look as well now as when we came in and anchored into it to leeward. All hands were on deck and getting ready for the stranding which seemed inevitable. Each man had had his work allotted to him, and at the moment when the cables gave would be in readiness at his post. The petroleum motor was going at full speed, and the vessel was kept well up to the wind and sea, by which means I hoped to ease a little the violent strain on the cables. We had anchored at midday on the 3d, and it was not till 4 o'clock on the 8th that the wind

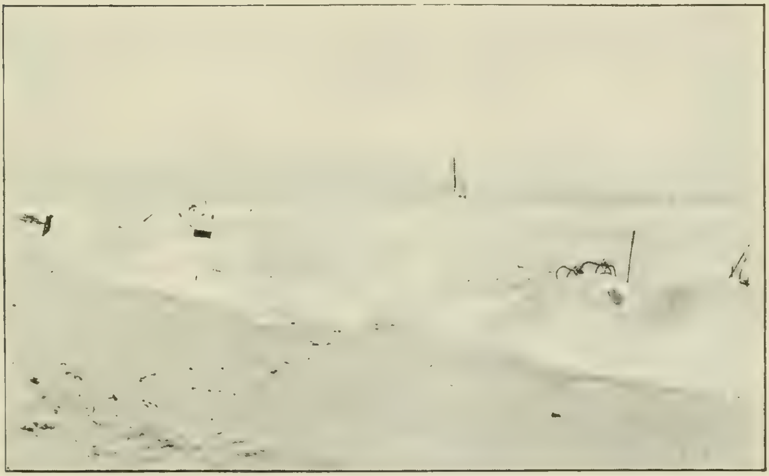
dropped sufficiently for us to get out again. Then another drifting night in pitch darkness among shoals and rocks, and then at last release. It is impossible to describe the well-being, the feeling of calm and safety, which came over us after these ten days of ceaseless fighting, when we dropped anchor on September 9, at half past 3 in the afternoon, at the head of Petersen Bay, in King William Land. There, approached by a narrow inlet, lay the harbor which was to be our place of sojourn for two years—"Gjöahavn," or Gjöa Harbor. A fresh land breeze prevented us from standing in, and it was not till the evening of the 12th that it fell sufficiently for us to beat up against it and drop anchor. Now we could breathe. We had done a good bit of work.

"Gjöahavn" was all that the heart could desire, small and land-locked. Low sandy land, covered with moss, rose gently upward from all sides until it reached a height of 150 feet, and thus formed a sheltered little basin where we could lie safe and snug. The day after our arrival here I rowed ashore with my instruments to ascertain the state of the magnetism in this area, and, strange as it may sound, we had found the very spot which, according to my scheme, was the most suitable for a magnetic station—about 100 nautical miles from the magnetic polar area. There was no longer any doubt; this would be our home for the next two years. The time after this was very busy. The vessel was hauled close up to the shore, which fell abruptly away, a conveying rope rigged to the masthead, and all our provisions passed ashore by means of it. Everything was put in order, and the house which we built covered over with a sail.

Then came the observatories, and of them a mushroom growth sprang up. First the magnetic variation house, then a dwelling house for the meteorologist and magnetician, the two latter being built of empty provision cases filled with sand. After that came the house for the absolute magnetic observations. The walls were built of blocks of snow, and the roof made out of thin, transparent sailcloth. Finally we built the astronomical observatory, which was known as "Uranienborg," this also being of snow, with a sailcloth roof. Besides all this building, we had done another good stroke of work in the shape of killing a hundred reindeer, and we had thus abundant provisions for ourselves and our dogs throughout the winter. The ice formed on October 1 and 2. The vessel was then covered with a winter awning, and everything got ready to receive the approaching winter.

On October 29 the first Eskimo made their appearance. Expectation on this point had always run high, and we had talked daily about meeting with them. Sir John Ross, in his description of his voyage, gives the word "teima" as the usual salutation between white man and Eskimo, and we had therefore carefully laid this

GJÖAHAVN.



ESKIMO CAMP NEAR GJÖA HARBOR.

word to heart in order at once to check any warlike desires, should they be apparent. This first meeting was exceedingly ridiculous and is one of our liveliest reminiscences. With two companions, armed to the teeth—namely, Anton Lund and Helmer Hansen—I started off to meet the Eskimo, walking first myself, with two comrades following me at about 3 paces' distance. They had shouldered their guns, and had such a fierce expression on their faces that it alone would have been enough to put a warlike detachment to flight, to say nothing of the five unfortunate Eskimo who were approaching us. The step and set-up of my detachment were unexceptionable. Arrived at about 100 paces from us, the Eskimo stopped, and we, not wishing to show less strategic ability, did likewise. Now, I thought, is the moment to set this matter at rest, and shouted "teima" at the top of my voice. It did not seem to affect them in the least, and, after a short parley among themselves, they recommenced their march on us. They were five in number, had formed in a sort of fighting line, and now advanced toward us, smiling and humming. Two of them had their bows firmly secured to their backs, and the three others were apparently unarmed. We, on our side, of course, reassumed our advance, repeatedly shouting, "teima, teima," and the Eskimo answered, but with quite another word—namely, "manik-tu-mi." We now approached one another quickly, and finally ended by meeting. It was a remarkable encounter. The Eskimo stroked and patted us both in front and behind, all shouting "manik-tu-mi" as hard as they could. We, true to our original plan of campaign, copied our adversaries, and shouted and howled, patted and slapped, to the best of our ability.

They were fine men, these Eskimo, tall and strongly built, and in their appearance reminded me more of Indians than of Eskimo, having the redskin type of complexion; they were, moreover, slim, and, as I said before, tall. The ordinary broad and fleshy Eskimo nose was exchanged for one better in shape, somewhat hooked; their hair was cut short, with the exception of a small crest of long hair which stretched from one temple round the nape of the neck to the other temple. We now proceeded, laughing the whole time, to the vessel. These Eskimo called themselves "Ogluli Eskimo," and looked upon the North American coast from Back River westward to Adelaide peninsula as their hunting fields. We made many good friends among this race, but it was not till later, when we met with the "Nechjilli Eskimo," that we made inseparable allies.

On November 2 the permanent station began its work. I will try, in as few words as possible, to explain terrestrial magnetism and the use of our magnetic instruments.

Terrestrial magnetic power is, with regard to direction and force,

different on every point of the surface of the earth, nor is it always the same in one and the same place. It is subject to regular daily and yearly changes, and, similarly, there often occur irregular, more or less violent, disturbances. Finally, small displacements show themselves from year to year, which continue in the same manner for a long series of years. All this has been discovered through observations undertaken during the course of time at various parts of the surface of the globe, partly during travels and partly by permanent stations. A careful study of all the available material which had been acquired by observation caused the great German mathematician and physicist, Gauss, in the thirties of last century, to form a theory as to the sequence and varied appearance of the phenomena of terrestrial magnetism at a certain moment of time according to the geographical latitude and longitude. It thus became possible to construct three different maps, of which two show the direction of the force and the third its strength. The reason why two maps are necessary for direction is because the direction must be given both in relation to the north and to the south geographical line, and in proportion to the horizontal plane of a place. The direction of the terrestrial magnetic force in relation to the north-to-south line can be observed by the help of the compass, which, as we know, generally points somewhat east or west of this same north. This divergence is called the variation or the declination. On a magnetic map lines are drawn which show the direction of the magnetic needle at every point of the earth's surface. These lines, which are called magnetic meridians, converge at two points—the north magnetic pole on the Arctic coast of North America, and the south magnetic pole in the interior of the Antarctic Continent. Each of the lines indicates, as will be understood, the direction one would go if he followed exactly the direction indicated by the north or south end of the magnetic needle. In the first case, one would at length arrive at the north magnetic pole; in the other, at the south magnetic pole.

If a magnetic needle be placed so that it can turn on an axis through its center of gravity—exactly like a grindstone—the needle will of itself adopt a diagonal position when the plane of revolution is identical with the direction which the needle of a compass indicates. An instrument of the kind is called an "inclinatorium," and the angle which the dipping needle forms with the horizontal plane is called the magnetic inclination of a place. Here, in our parts, the north end of the needle points down toward the earth; in Australia, on the contrary, it is the southern end which dips. At the north magnetic pole the dipping needle assumes a vertical position with its north end down; at the south magnetic pole it assumes a vertical position with its south end down. The inclination, then, at both their points is 90°, and decreases according as the distance becomes

greater from them. On a series of points within the tropical zone the inclination is 0°; that is to say, the dipping needle places itself exactly horizontally, and that line which we may imagine as drawn through all these points is called the "magnetic equator." It is situated partly above, partly beneath, the earth's geographical equator.

The force of terrestrial magnetism works, as will be understood, with its whole strength in the direction given by the dipping needle, and it may be asked, How great is this force in the different places? In order to discover this we must imagine the force dissolved into two parts, one part working horizontally, and one part working vertically. It is evident that it is the horizontal part of the force which causes the needle to take a set position, and if we know all about this force—"horizontal intensity," as it is called—and at the same time know the inclination, it is easy, by a simple calculation, to find the collective strength, the total intensity. For the determination of horizontal intensity two methods are adopted, either independently, preferably, for the sake of comparison, simultaneously. One method consists in placing a magnetic bar by the side of a needle at a given distance from it, and observing how many degrees the needle moves away from its original position. It is clear that the weaker the horizontal intensity the greater the oscillation of the needle, and when the strength of the magnetic bar is known, it is possible, by the aid of the angle of oscillation and the distance, to calculate the horizontal intensity.

The other method is to note the time of oscillation of a magnetic bar suspended by a thread in such a manner that it can revolve in the horizontal plane. When the magnet is allowed to be at rest it sets, under the influence of horizontal intensity, in the direction of the needle. Brought out of equilibrium by a little push, it will swing backward and forward, and the stronger the horizontal intensity the sooner it will come to rest again, or, in other words, the shorter will be the time of each individual oscillation. When the strength of the oscillatory magnet is known and observation is made of how many seconds are necessary for an oscillation, the horizontal intensity can be calculated.

Maps are constructed to give an idea of the value of horizontal intensity, expressed in so-called electric units, on the different parts of the earth. A line passes through all the places where the horizontal intensity is the same. The horizontal intensity decreases toward the magnetic poles. It is therefore matter of consequence that terrestrial magnetism here, where the inclination is 90°, acts with its whole strength vertically downward, and thus can not have any effect in a horizontal direction.

Although the magnetic maps are very dissimilar, they are alike in

one respect, namely, that the magnetic poles are the points of mark on the surface of the earth, and it is obvious that magnetic investigations just at these points, or in their immediate vicinity, must be of the greatest interest to the science of terrestrial magnetism. The Gauss theory by no means solves all the riddles presented by the phenomena of terrestrial magnetism, but continual efforts are being made to decipher these problems by the collection of as reliable and comprehensive observations as it is possible to procure.

The magnetic work of the *Gjöa* expedition is intended to be a contribution to this object. But the difficulties were not small. The very fact that horizontal intensity, as we have heard, becomes, in the vicinity of the magnetic poles, so infinitesimally small, renders necessary extraordinary precautions for the determination of this itself, as well as of the variation. The *Gjöa* expedition's equipment of instruments was calculated for this purpose. The magnets, fourteen in number, were chosen with great care in Potsdam just before our departure. The inclination we were able to determine by the help of three inclinatoria of varying construction, and for the determination of the declination we had two different instruments.

Added to these was a set of self-registering variation apparatus; that is to say, three instruments permanently erected in a dark room, each instrument containing a small magnetic needle, two of the latter being suspended by a fine quartz thread, the third oscillating on a fine bearing in such a manner that the needle with its movements followed the declination, the second the horizontal intensity, and the third the inclination, even its minutest changes. Each needle was provided with a looking-glass, which reflected the light from a lamp onto a drum covered with photographic paper, which, by means of clockwork, made one revolution during the course of the twenty-four hours. It was arranged so that the reflection from each of the three needles struck the drum at different heights and caused a little dark spot, but when the drum with its paper revolved, each of these spots was continued, forming a consecutive dark line. There were thus three dark lines across each other on the paper when after the lapse of twenty-four hours it was taken off.

After what we have already heard, it will easily be understood that it would not have done to select the pole itself for a permanent observation station, even had we known beforehand its exact situation, and could have foreseen that it would keep immovable on one of the same spor. Advised by Prof. Adolf Schmidt, I therefore decided to make the base station, where the instruments for variation were to be erected, at such a distance from the pole that the inclination would be about 89°. This requirement was fulfilled by Gjöahavn, which accordingly became our headquarters. We constantly made excursions hence to adjacent parts of the country, and right in

to Boothia Felix, where I succeeded by the help of declination in absolutely proving what of late has been assumed on theoretic grounds, namely, that the magnetic pole has not an immovable and stationary situation, but, in all probability, is in continual movement. In what manner this movement takes place our considerable amount of material acquired by observation will, when it has been worked out, give instructive information.

The magnetic observations were kept going day and night, without interruption, for nineteen months. Meteorological observations were also taken the whole of the time. Professor Mohn had equipped the expedition with a complete set of meteorological instruments, and made it his business that the meteorologist of the expedition should receive the best instruction. The meteorologist, Dr. Aksel Steen, was my magnetic counselor at home in Norway before the departure of the expedition, and many a good bit of advice did he give me. The astronomical equipment was for the greater part due to Professor Geelmuyden.

The Eskimo came and went now as often as they liked, and in a short time became quite at home with us. Toward Christmas they all disappeared, with the exception of an old man, Teraiu, with his wife, Kaijoggolo, and little son, Nutara. They came and lived with us during the whole of the coldest part of the winter, the rest of the tribe having gone westward to capture seal.

Christmas was now approaching with rapid steps, and countless preparations were made. The days had begun to be shorter and the cold sharper. Then came Christmas eve, the first on board the *Gjöa*. The weather was splendid, absolutely still, and sparklingly bright. The thermometer —40° F. (—40° C.). And what a Christmas eve it was out here. Was not heaven itself sending us a greeting? The most glorious aurora we had yet seen lighted up the entire sky in chasing rays from the horizon toward the zenith. The rays seemed to be racing one another, racing to see which would be the first in the wild chase. Then they all suddenly unite, as if at a given signal, and change into the shape of a soft, delicately formed ribbon, twisting in light and graceful movements. It is as if the unquiet beams had now sought rest. Are they, perhaps, thinking of something new? Then suddenly the beautiful ribbon is, as it were, torn in many pieces. Again begins the chase, again the wild flight. It is difficult to imagine what the next step will be. It seems as if the zenith would now be chosen as the central point for the whole movement. And so it is. Suddenly, as if by magic, the most glorious corona streams forth from it.

Christmas goes, the New Year comes. The many holidays have already begun to tire us, and we take up our work again with pleasure. The first item on our program is the equipment for my

approaching sledge journey to the immediate area of the magnetic pole. The original plan was that I should make this expedition with one companion and provisions for three months, supported by a relieving expedition under Lieutenant Hansen with one man. There were consequently four of us who were obliged to have our things in order by a certain date. In one thing there was a consensus of opinion, namely, that Eskimo fur garments were the most suitable for this climate. We had therefore taken time by the forelock and bartered with the Eskimo for the lightest and finest reindeer-skin clothing we could get. After many small trials, too, we all agreed that snow huts were far superior to tents when the temperature was below —22° F. (—30° C.). I therefore started a class, with old Teraiu, the Eskimo who stayed with us, with his family, as teacher. We all four joined and now built a snow hut regularly every forenoon. Sometimes one of us was master builder and the others masons; sometimes another. Old Teraiu, who could not understand what we were building all these huts for, shook his head pensively, evidently in the conviction that we had taken leave of our senses. Sometimes he would throw out his arms to indicate the overwhelming number of houses, and exclaim, "Iglu amichjui—amichjui—amichjui!" Which means, "This is a dreadful lot of houses." But in this, too, we arrived at what we wanted: we became at last good snow builders.

On February 29 we took our sledges up on to the heights in order to be ready for a start the next morning. The day for the beginning of our sledge journey broke clear and still. The temperature was not exactly summery, the thermometer reading nearly —64° F. (—53° C.).

One sledge had a team of seven, mostly young dogs, for we had lost all the others during the course of the winter from one or another mysterious disease; the other sledge was hauled by three men. We found it difficult to make any way: the sledges ran badly. The snow in this severe cold was like sand, and advance very heavy. After terrible labor we made 4 miles the first day. Before we could go to rest we had to build our house. Thanks to the many huts we had built before that winter, we did this fairly quickly—in about an hour and a half. The temperature, which had sunk to about —70° F. (—57° C.), did not tempt us to be out longer than was absolutely necessary. As soon, therefore, as we had finished the hut, we went in and walled up the entrance with a large block of snow. The cooking apparatus was set going, and it was soon warm and cozy in our little snow house. In spite of the low temperature—about —77° F. (—62° C.), the lowest we observed—we spent in all respects a comfortable night. The next day, after ceaseless toil from morning to evening, we managed to cover 3½ miles. I realized now that this sort of thing

was not good enough and decided to make the depot where we were, return to the vessel, and wait for warmer weather.

On March 16 I made another attempt to move this depot somewhat farther out. It was on this trip that we first met with the Nechjilli Eskimo, and accompanied them home to their snow huts, which lay among the pressure ridges in Rae Strait. Our first meeting with this tribe was thoroughly friendly and hearty. Their camps consisted of sixteen snow huts, inhabited by about a hundred people. In appearance and dress, they were exactly like our former friends the Ogluli Eskimo.

When my companion and I were about to begin to build our house of snow, they all came and gave us to understand that they wished to help us. We gladly left the work to them, and after the lapse of half an hour our hut was completely finished. The following morning occurred a scene which very clearly shows in what respect the whites are held among these savages. From our earlier Eskimo friends, the Ogluli Eskimo, we had learned that the word "miki" meant a dog. As all our dogs were young and not up to much work, I asked one of our new friends—a man named Attikleura, who appeared to be the chief of the tribe—to lend me his dogs the next day. He thought a good deal when I asked him to do this, looked at me, and smiled faintly, but made no answer. I, however, did not give in, but repeated my request. He nodded his head, and we did not mention the matter again, as I now considered it settled. When I came out of the hut in the morning, Attikleura's little son was standing near the door. I did not take much notice of him, but went on to his father's hut to ask what had become of the dogs. I naturally used the word "miki" which I had learned. He looked at me in astonishment, and made me understand that I had got his "miki." As I persistently denied this, he made signs to me that we should go out. He went straight over to his little boy, pointed to him, and said, "ona mikaga," which is to say, "here is my boy." Now everything was clear to me. "Miki" did not mean with this tribe "dog," but "child." So great was then their fear of us that he had without demur given his son away. I let him understand that I had made a mistake; the whole thing ended by hearty laughter on both sides.

After two days' march we came across, at Matty Island, a small camp, consisting of six huts. These belonged to some Ichjuachtorvik Eskimo, as they called themselves, who were from the east coast of Boothia Felix, near the place where Ross wintered in the *Victory*. These people made a very bad impression on me, and I said to my companion in the evening that we had better lash everything securely on the sledges, and let the dogs sleep near them. In the morning when it was time to start we missed a saw, an ax, and a knife. I made the Eskimo understand that they must return the stolen articles, but they

pretended that they had no knowledge of the matter. After addressing myself to them two or three times in vain I grew tired of it, and got out one of our carbines. I then explained to them as well as I could that I knew who the thieves were, and that I would shoot them if the articles were not given back. This worked. The things were returned in a hurry. I did not dare to make any depot in the neighborhood of these thieves, but retraced my steps, and confided everything to the care of our new friends, the Nechjilli Eskimo. I was never disappointed in the confidence I placed in these people; they were what they appeared to be from the very first moment—thoroughly honest. Quite a crowd of them joined company with us, and returned to the *Gjöa*, staying with us for a few days.

On April 6 I started off with Sergt. Peder Ristvedt to make magnetic investigations in the vicinity of the pole. We were equipped for three months, but our nine dogs were not equal to drawing the heavily loaded sledges. We had a couple of Eskimo with us who were going out to capture seal. It was a lovely day, and curious as it may sound, felt quite summer-like, with a temperature of —22° F. (—30° C.). We had, of course, been used to a much lower temperature during the two preceding months, February giving an average of about —45° F. (—43° C.). This was the reason why we perspired as if we were in the Tropics that day with its —22°. We had to throw off garment after garment, and only stopped when modesty demanded it of us. This sledge trip was not very successful. An injury to my leg, which I incurred, kept me lying in my bag for a week. I had, however, the satisfaction of getting as close to the pole as was necessary. We had been obliged on our way to cache one of our sledges and provisions for a month in order to hasten our advance. This was unluckily in the neighborhood of the Ichjuachtorvik Eskimo hunting grounds. When we came back to fetch our things, everything, with the exception of 10 pounds of pemmican, had been stolen. We were thus obliged to return home after only two months' absence.

In the beginning of June large numbers of Eskimo appeared at the ship with blubber and skins of seals for sale, which they had caught during the course of the winter months. We paid them in wood and iron. In the middle of July most of them left us again in different directions to hunt reindeer and catch salmon. In the summer of 1904 Lieutenant Hansen went on a rowing expedition with one man to Cape Crozier, about 100 miles distant, to put down a large depot. The latter was for use on his sledge journey to the east coast of Victoria land, planned for the spring of 1905. Gustav Wiik had all this time had sole charge of the magnetic observations of the station, and had done excellent work. The summer was short and cheerless. The vessel slipped the ice on July 22. Of birds of passage we saw

swans, geese, loons, ducks, eiders, and many small birds. The ptarmigan came in March and went in November. The only stationary animals were the Arctic fox, the stoat, and the lemming. The vegetation was rich, and large tracts were to be seen quite covered with flowers. There were butterflies, flies, and some other insects, not to omit several milliards of gnats. The winter set in somewhat earlier this year than the preceding one, and the ice formed a week sooner. The reindeer, of which there had been great numbers the previous autumn, were this year very seldom to be seen. The whole of our winter provision thus consisted in 1904 of only 20 deer, and these we had shot far inland, whereas in 1903 we could have killed as many as we liked quite close to the vessel. However, the Eskimo, who had spent the summer reindeer hunting in northern America, brought us a quantity of venison, and from other quarters we procured salmon, cod and trout, so that we were well provided for the next winter too. In the middle of October the Eskimo returned from their summer excursions, and then visited us in great numbers, but went off again to fish before the darkest part of the winter set in. Toward Christmas they returned to the vessel, and we then had the pleasure of their company for nearly two months. On November 20 we had a visit from an Eskimo family of a quite strange tribe. They proved to be Kinepatu Eskimo from Chesterfield Inlet, near Hudson Bay. The man's name was Atagala. He knew English sufficiently to explain that near where he lived two large vessels were lying. For an old Mauser rifle and 400 cartridges he undertook to take a mail down to them and return with an answer, about 1,500 miles. On May 20, the next year, a sledge team of 10 dogs swung into our harbor. It was Atagala. He brought us a mail from the *Arctic*, a ship belonging to the Canadian Government, which was wintering at Cape Fullerton, in Hudson Bay. She had originally been the *Gauss*, and was built by the German South Polar Expedition, but was now out to inspect and choose suitable spots for small garrisons. Major Moodie was in chief command, and Captain Bernier in command of the ship. An American whaler, the *Era*, was also wintering at the same place. Captain Comer, of the *Era*, and Major Moodie sent me 10 sledge dogs, as I had written to the former, stating that the greater number of our dogs had died in the course of the first winter.

During our seventeen months' intercourse with the Nechjilli Eskimo we became by degrees so intimate with some of them that they little by little lost the mistrust they usually have for strangers, and showed us complete confidence. We, however, never really acquired their language, and consequently could not thoroughly understand their life. What I have to tell about them, however, is based partly on careful observation and partly on information from the Eskimo themselves, and this being the case, I venture to think

that my information regarding one of the most interesting and least-known races of the world is correct. What adds greatly to the value of these searches is the series of splendid photographs taken by Lieutenant Hansen during our sojourn in those parts.

Nechjilli, which the Nechjilli Eskimo look upon as their home, are the banks of the great Willersted Lake, on Boothia Isthmus, and of the little bit of river which flows from the lake into the sea. Unfortunately, we never had time to pay them a visit, but from the Eskimo's often repeated descriptions I know what the country looks like and what their life is there. From the time the ice breaks up in June or July to January or February the next year, it is here that they live—in summer in their tents, and, when the snow falls, in their snow houses. Often in transition periods, from winter to summer and summer to winter, when the snow—as it is in the month of June—is too water-logged to be used for the building of entire snow huts, they are obliged to use a structure the walls of which consist of snow and the roof of skins, a combination of snow hut and tent; or, as often happens in September, when the cold strikes in and the lakes freeze before the snow comes, they are obliged to construct a building of ice with a skin roof.

When an Eskimo is about to build a snow house, he is always careful first to consult his "hervond." This is simply a stick of straightened horn taken from the antlers of the reindeer. At the lower end it has a ferrule of musk-ox bone and at the upper a handle of reindeer bone. It is about a yard long. With his keen glance he now scans the country, and at the place which pleases him best thrusts his "hervond" into the snow. He does this in order to find out its quality, for it is as important for an Eskimo to find good snow for his building as it is for a bricklayer to have lime for his bricks. A very long experience is required in order to test the snow in this manner, and, when several Eskimo are together, it is a task generally left to the oldest ones. The most suitable snow is that of a solid and compact kind, with a superincumbent layer of loose snow, about a foot in depth. Nor must the underlying snow be too hard, or it will be difficult to cut out the blocks. The site once chosen, the upper loose snow is shoveled away and is laid round the spot where the house is to be. When the underlying hard layer is laid bare, the builder begins with his knife—which is usually long bladed and long handled—to cut out and build up the blocks. The house is constructed from inside, and the blocks are cut exclusively from the building site. It is seldom that an Eskimo has resort to the snow outside. The blocks are cut out of snow with a high edge, and that is the reason why the site can contain sufficient material. The hut is built spirally, in such a way that the succeeding block is always supported on a preceding one, and in shape much

resembles a large beehive. Our greatest difficulty was always when we had to decrease and build the roof. The blocks are then placed in a very inclined position, one may say almost rocking. But the Eskimo are born to this way of building. Where one of them puts the block there it stays, even if it forms an angle of 45° with the horizontal plane. The structure is completed by a little, dexterously placed, plug of snow in the apex of the roof. After the house is up, there will be a mass of refuse snow lying inside it. With this the sleeping bench and fireplace are made. Meanwhile the lady of the house has not been without occupation outside. The loose snow, which was shoveled away at the beginning, she uses to calk all the holes and cracks with, and if she has any to spare she throws it over the entire house, which helps a very great deal in making it warm and draftless. When all is finished inside, an aperture is cut in the wall of the same height as the bench. The man comes out and the woman takes his place. First of all, the large water-tight kayak skin is handed in and is spread over the entire bench; then comes the turn of all the reindeer skins—soft, large and warm; then the rest of the effects, such as cooking utensils, a drying grill, blubber for the lamp, and a number of other things which the Eskimo find indispensable. When all this is done, the housewife is walled in. It will be asked, What was this immured lady doing inside the hut? Perhaps it will not be indiscreet of me to poke a little hole in the wall and peep in. In the name of knowledge everything is permissible, so with a "ski" staff, which I happened to have with me, I made a hole in the wall and opened a way into the sight of this mysterious interior.

The first thing she does is to put the lamp in place and make a fire. After that she fills the cooking pot with snow and hangs it over the flames to melt into water for her thirsty husband. As soon as she is satisfied that the lamp flame is burning to its greatest extent, she turns her attention to arranging other things: the sleeping bench is leveled and flattened, reindeer skins placed in order on it, and everything made as comfortable and cozy as possible. All being arranged, she seats herself before the fireplace and seems to be particularly anxious to make the fire burn as brightly and give out as much heat as possible. Now I understand why it is she is walled up in this house—in order to warm it and make the blocks of snow sink, so that the whole will form a close and compact wall. But she will certainly not succeed in this if I continue at my peeping, so I fill it up again and take myself off. Meanwhile, the man has built the passage, 9 to 12 feet in length, which leads into the house. But he will certainly not dare to make a hole in the wall and put it in communication with the interior of the house before he receives higher orders from his better half. He amuses himself meanwhile with his friends, who are

in a similar situation, and whiles away the time in joking and conversation. They are a fine group of men who are standing there, ranging tall, from 5 feet 9 inches to 6 feet, though there are some short ones among them. They are powerfully built, the life they lead inducing all-round development. The ladies' pellucid voices are now heard, and the expectant husbands can complete their structures by knocking a hole through the wall from the passage to the hut.

Let us now pay a visit to one of these camps and see what Eskimo life is here in these burrows of snow immediately after their construction. The huts are of different sizes. Some people like them high, some low. The circumference is from 30 to 45 feet, according to the size of the family. It is the month of January, and the cold is severe. They, therefore, live two families together, so as to be warmer. The members of the family have just assembled after the building operations and a long day's sledging. The housewife sits in her accustomed place and croons her monotonous chant, consisting of four words and as many notes, which are repeated in varying forms. These sounds, when repeated often enough, we found unendurably monotonous. Politely to request them to be quiet was of no use: but we found another most effective means, namely, to give a vocal performance of our own at the same time. Then we had peace, for our many tones, no doubt, sounded as awful to Eskimo ears as their four did to ours. Well, this was not very polite on a first call, but anyhow they were not offended.

The first thing an Eskimo does when he enters his hut is to take off his outer coat and beat all his clothes quite free from snow. This he does so that the latter shall not have time to melt and wet his clothes. If he intends to be in the whole evening, he takes off his other outer garments. If any of them have become wet during the course of the day they are thrown to the lady of the establishment, who puts them upon the grill to dry. His hunger has now to be appeased, and the most tempting pieces of meat and fish are brought out—of course, frozen stiff. But this does not affect the Eskimo in the least: once down, it melts soon enough, and enormous quantities disappear. Their knives are their only eating implement, but these they handle with dexterity. They hold the piece of meat fast with their teeth and the left hand, and with lightning rapidity pass the knife right under their noses and cut off a piece of meat so close in to their lips that one is astonished that the latter do not go too. One large bit of blubber after the other goes the same way.

The family having thus finished this important business, a nap will possibly be to their taste, and the entrance is carefully bricked in from the inside. They now proceed to undress till they are quite naked, and then sleep the sleep of the just under large coverings of reindeer skin shared in common, possibly till late the next day. This, how-

ever, depends upon whether they have enough food. If the man intends to live here for any length of time, he chops himself a window the following day out of the ice on the nearest fresh-water pool and inserts it in the wall immediately above the entrance. His dame can then see to do her work by daylight. She has plenty to look after. She sits by the fire, which is her accustomed place, with her legs tucked up under her, and watches the flames and her offspring, who are running in and out playing. She smiles and looks absolutely happy. Probably it is the two small physiognomies, incrusted with soot and train oil, which call these pleasant thoughts. It is not so long since the youngest left her hood, where children are carried till they are about 2 years old. Their play grows less by degrees, and the youngest one goes up to his mother and looks inquiringly in her face. She knows her boy, she does. The children here are not weaned so quickly, and mother's milk is to their taste long after they begin to walk. I have even seen boys 10 years of age lay their arrows aside and take part in the repast.

But see, here comes a friend—of the same sex, of course. She has come to pass the time of day—is bored, perhaps, in her own hut. It is Alo-Alo, a young and attractive woman. The sharp cold has given her a fresh color, and the pretty brown eyes with the blue whites look very much as if they could hide something behind them. Out of her hood sticks up a little wondering face; it is her year-old son "Akla," or the brown bear. Conversation is soon in full swing, and the two women seem to have a great deal that is amusing to tell one another. Suddenly the baby in the hood begins to move, and with incredible rapidity and quite unparalleled adroitness changes place from the hood to his mother's lap. He has his wishes complied with and is going to be put back in his warm, cozy place, when his mother discovers that he is more than usually dirty today. The washing process which then takes place must be very economical when water is scarce. She licks the child clean, and then puts him back.

If it has been a fine day, the men have been out on the ice to capture seal, and are now coming back in the dusk. They seldom return home empty-handed, but have a seal or two with them, which are then handed over to the housewife, who has to see to their partition. The entrails, which are the greatest delicacy they know, go to the one who has caught the seal; the rest is divided among all. After supper they often require a little diversion in the long winter evenings. They then assemble in the largest hut and spend a few hours together, singing and dancing. These huts are often quite handsome structures, and I have seen them 14-feet high and 25 feet in diameter. On these occasions the women all sit round in a circle and begin their monotonous chanting, the men entering the circle one by one to perform a kind of solo dance, beat a frame covered with thin tanned

reindeer hide, and scream something perfectly dreadful. What astonished me most at these festivities was the singing of the women. I had always thought that all their tunes—or rather variations on the five notes—were impromptu, but here I had certain proof that they really were songs, for I heard as many as twenty women singing together at these gatherings for a whole hour at a time, without any of them falling out of the melody. In my opinion this almost points to musical gifts.

The next evening the magician of the tribe will perhaps give a representation in the same hut. This is a very serious affair—the only performance to which we never had an official invitation. We tricked them, all the same, and found out what went on. The hut is made almost dark, only a little flame being allowed to burn, which, of course, made things the more mysterious—complete darkness would be too dull. The magician and his assistant (usually his wife) take their places on the bench, and the company sit at the other end of the hut. Absolute darkness broods over the performers. The two now begin to utter loud howls, and, on the whole, lead one to suppose they are killing one another. After this farce has been going on for half an hour the noise grows less, and by degrees everything becomes quiet. The light is made stronger, and, to the apparent surprise of everybody, the magician now exhibits two holes in his coat, which, before the light had been subdued, was quite whole—one hole in his chest and the other in his back, and they go to prove, of course, that during this turbulent scene he has run himself through with his spear. Judging by appearances, the Eskimo all take this very seriously; but when later I joked with them about it they laughed and said that the whole thing was nonsense.

Any real sign of astonishment these people seldom show. One of the few times that I can remember seeing any trace of this was when I sent a messenger to the ship—I was then in camp about ten miles away taking magnetic observations—with a letter in which I asked for a certain quantity of ammunition. When he returned the next day and I told him before he gave me the consignments that I knew how many cartridges he had with him of each kind and that he might count them himself, he was astonished to see that I was right, and much impressed by the use to which we put our writing. They often amused themselves later by scribbling some strokes on a bit of paper and giving it to us. We always pretended to be highly astonished, and read it out loud; this greatly amused them. Family life gave us the impression, as a rule, of being happy, though I know of cases where the husband ill-treated his wife. The male sex being so much more numerous than the female, it was not unusual to find marriages where the wife had two husbands. The reverse relationship I never met with. In general, the husband was spokesman and the

VEGETATION AT KING POINT.

DRIFTWOOD AT KING POINT.

wife obeyed blindly, but elderly widows were sometimes personages of great influence.

The religious opinions of the Eskimo were like our own in that they had an understanding of a good and an evil being, of punishment and reward. If a man had behaved as he should in this life, then he would go to the hunting fields in the moon; and had he been a bad man he must go under the earth. During the whole of our stay among them there only occurred, as far as I know, four births and two deaths, the latter in both cases being suicide. It is not considered to be wrong, but is, however, only resorted to when the pain in an illness is too great to be borne. The way in which they do it is, I think, peculiar to them alone. A sealskin thong is stretched across the hut 2 feet above the floor. The sick person is left alone in the hut, and the others go outside. They, however, have peepholes in the wall, through which they follow events. The sick person now kneels down and endeavors to suffocate himself by pressing his throat against the strained thong. If the unfortunate person is unable to do the business for himself, or it seems to be taking too long, one of those outside comes in and expedites matters by pressing his head down on the thong. Fighting with closed fists occurs now and then, and murder is not unknown. It thus happened in the summer of 1904, at the station, that a boy 12 years of age accidentally shot another boy of 7 in a tent. The father of the boy who was killed immediately seized the other, who, for that matter, was his adopted son, and dragged him out of the tent and stabbed him to death. Their dead they sew up in a reindeer skin and lay them on the ground. A few articles, such as a bow, spear, arrows, and other things, are placed beside them. We found many an interesting object in this manner.

On April 2 Lieutenant Hansen and Sergeant Ristvedt started on their sledge journey to chart the east coast of Victoria Land. They had two sledges, twelve dogs, and equipment for seventy days. The provisions were measured as shortly as possible so as to reduce weight. All the same, it is very necessary on a long journey of the kind that everything should be carefully planned so as really to hold out the requisite time. The depot, which had been made the year before, had been entirely spoiled by bears, but Lieutenant Hansen and his companion shot bears, seals, and reindeer, and thus spun the journey out for eighty-four days. Excellent work was done. The east coast of Victoria Land was charted right up to the seventy-second parallel. The land formerly seen by Doctor Rae at the south end of Victoria Strait proved to be a group of over a hundred small low islands. These we e charted on the way back. An interesting event from this journey was the meeting with another unknown Eskimo tribe, the "Kiilnermium Eskimo," whose hunting fields extend from the Cop-

permine River eastward. These Eskimo, like the others mentioned, have no connection with civilization. We, of course, received our bold companions with flags waving on their return, and a feast to commemorate it.

On June 1 we dismantled the observatory containing the magnetic self-registering instruments. For nineteen full months Wiik had kept this going, and had done work which will, without doubt, be rich in results.

On August 13, at 3 o'clock in the morning, we continued our way westward, and I am not sure that the little brown-eyed people in there on the beach were quite cheerful that morning. Hardly, for they were losing several rich and great friends. They waved long to us—probably a farewell for life; and if some traveler many years later pays this place a visit, the numerous tent rings will remind him of the many happy days the *Gjöa* expedition spent here with their friends the Nechjilli Eskimo. The day afterwards we stopped at a place called by the Eskimo, Kamiglu. Here we took an Eskimo boy named Manni on board. He won us one and all by his openness and honesty, and even the cook, who hated Eskimo, had, I think, a warm feeling somewhere at the bottom of his heart for him. It was my intention to bring him home and show him a little of the world he could never have imagined, and to send him back again, in the event of his wishing it, but he was accidentally drowned at Herschel Island. After passing through narrow and shallow waters, we came out on August 21 in Dolphin and Union straits. Now we could breathe. On the forenoon of August 28 we sighted a sailing ship. It was a proud moment for us all when we hoisted our flag and bore down on the American.

On September 3 we were stopped by ice at King Point, and soon after that were beset for a third winter. However, we were in high feather all the same. On the shore lay the finest driftwood that could be desired, the sea was full of fish, and not far off there were hares in thousands. On the shore, some fathoms in past us, lay the nipped whaler *Bonanza*. The first thing we did was to build ourselves a house of drift timber, and after that the observatories were put up. From October 20 to March 12 I was out traveling with the *Gjöa's* mails, Lieutenant Hansen having command on board meanwhile. This winter was exceedingly severe and disagreeable. On my return everything was in the best order, but on March 26 Wiik became ill and had to take to his berth. He died on the 26th. It was a hard blow to lose a comrade so near home. It was not until May 9 that we were able to bury him, the ground up to then being too hard frozen. In the meantime his coffin stood in our dwelling house on shore, which we gave up to it, nailing up the door. Later on we put up a large cross with an inscription on it at the north end of his grave, and

ESKIMO CAMP AT KING POINT.

INTERIOR OF SNOW HUT.

ESKIMO BUILDING SNOW HUTS.

ESKIMO IN SNOW HUT.

when the flowers came decorated it with them. It is situated on a very prominent point, and will be a landmark for the numerous ships which pass by it.

The spring was a cheerful time. The continual passage of Eskimo and whites made the time pass quickly. On July 2 we got out of the ice and brought up under the *Bonanza*, so as to avoid the ice which was drifting backward and forward in the land lead.

On July 11 two of the American whalers came to our place to collect driftwood, and the same evening we stood out. We took a last farewell of our comrade whom we were leaving behind us out there, and dipped our flag as a last mark of honor to him as we passed under his grave. Already at Herschel Island we were stopped by the ice, and were kept there a whole month. After many narrow passages and abrupt turns we stood down Bering Strait on August 30. The day afterwards we went into Nome, a gold-digging town in Alaska. The reception we received and the enthusiasm our enterprise had aroused there we shall never forget.

On September 5 the *Gjöa* set sail southward under Lieutenant Hansen's command for San Francisco, and on the 7th I left with the magnetic instruments for Sitka, in order to conclude our work. On October 19 we met again in San Francisco, where we confided the vessel to the hands of the American Navy. There rests the old *Gjöa*, and greatly does she need it.

ICELAND: ITS HISTORY AND INHABITANTS.[a]

By Herr Jon Stefansson, Ph. D.

I.

Geographically and geologically Iceland is part of—a continuation of—the British Isles, for it is situated on the same submarine mountain ridge, stretching from southeast to northwest across the North Atlantic, the average depth on it being 1,500 feet to 2,000 feet, while north and south of it 12,000 feet is the average depth reached by sounding. According to Prof. James Geikie, land connection between Greenland and the British Isles must have existed in Cenozoic times, for relics of the same Tertiary flora are found in Scotland, the Faroes, Iceland, and Greenland. The deposits in which this fossil flora occurs are associated with great sheets of volcanic rocks. This so-called Iceland ridge (or Wyville Thomson range) was at all events greatly upheaved in the Tertiary period, and thus an island, misnamed *Iceland* in the ninth century, 40,450 English square miles in extent, the largest island in Europe after Great Britain, rose out of the Atlantic, distant only 450 miles from Cape Wrath, on the northwest coast of Scotland, to Stokknes, in the southeast of Iceland.

It is as rational to call this island Iceland as it is to call an ice sheet measuring several hundred thousand square miles Greenland. Iceland is not a bleak, arctic region, embedded in thick-ribbed ice, though its northmost peninsula, Rifstangi, projects about a mile north of the Arctic Circle. Situate between 63° 24′ and 66° 33′ north latitude, yet its thermic anomaly is such, owing to the Gulf Stream, that the mean temperature of the month of January at Stykkisholm, on the west coast of Iceland, is 34.5° F. higher than it should be in that latitude. It is surprising that January at Reykjavik is milder by 1½° than at Milano, North Italy, or 1° F. milder than at Munich on 48° 9′ north latitude, i. e., 3½° farther south than London (51° 33′ north latitude), while the mean annual for the same place is but 1°

[a] Reprinted, by permission, from the Journal of Transactions of the Victoria Institute, or Philosophical Society of Great Britain, 1902, Vol. XXXIV, pp. 164–178; 1906, Vol. XXXVIII, pp. 54–63.

less than at St. Johns, 16° farther south, namely, 39.5° F., or as much as that of parts of Asia situate over 17° (over 1,000 miles) farther south. Grimsey, off North Iceland, cut in two halves by the Arctic Circle, is 5° F. warmer in January than Stockholm. The coolness of the summer, however, reduces the annual mean. The mean temperature of summer at Reykjavik is only 53° F. (July, 59.20° F.). The sea round the south, west, and east coasts of Iceland is never less than 41° F., while on the north coast the nearness of polar ice drifting down from Greenland occasionally, every four or five years, causes a fall in temperature.

It will thus be seen that Iceland has a temperate climate, while the clearness of its atmosphere rivals that of Italy. "A medium of matchless purity" this combination of sea and mountain air has been well called, and it is most bracing and exhilarating—"like drinking champagne," an English traveler says in her book on Iceland. It is freer from microbes than the air of any part of Europe, and, according to the researches of Dr. W. L. Brown, the blood of an Icelander does, on an average, contain more hemoglobin than that of other inhabitants of Europe.

No country on earth of equal size contains so varied and wonderful natural phenomena. The glaciers of Switzerland; the fjords, salmon rivers, and midnight sun of Norway; the volcanoes, grottoes, and solfataras of Italy, on a grander scale; the mineral springs of Germany; the geysers of New Zealand; the largest waterfall, next to Niagara, in the world, the Dettifoss, all are here. Nowhere has nature been so spendthrift in giving a geological lesson to man. If there be sermons in stones, volumes lie unread here. Here we see her Titanic forces at work building up a country.

Let us approach this wonderland. A high tableland, out of which rise sharp peaks and glittering ice fields, and into which run winding fjords, fringed by rocky islets on which the waves break in a white line of foam. You do not miss the forest, which is not there, for the vivid brilliance of the air shows the glacial white and volcanic black, and sunset turns them to rich purple and violet.

Iceland is a plateau region composed of older and more recent volcanic masses, not older than the Tertiary period, of an average altitude of from 1,650 to 2,000 feet, occupying thirteen-fourteenths of the island. It consists of basalt and palagonite tufa and breccia; the latter, the younger formation, in the center and toward the south, while the greater part of the west, east, and north coasts is of basalt, or nearly two-thirds of the island. The glaciers rise like broad domes from this plateau. In the south, where the glaciers come down to the sea, there are no harbors for 250 miles, from Djúpivogr to Eyrarbakki, for all the fjords have been filled up with detritus brought down by the glaciers. But the basaltic regions are cut and furrowed

by numerous fjords. The basaltic formation is divided into two strata by the "surtarbrand"[a] formation of the Miocene period, 60 to 100 feet in thickness, the fossiliferous layers occurring about midway up in the vertical faces of the basalt of the northwest. In these lignite strata have been found the remains of a vegetation of the American type when Iceland had a tropical climate.[b] The extensive forests of Tertiary times seem to have been overwhelmed by pumice, ashes, and sometimes by flowing lava. Silicated tree stems are found in many places. The area of glaciers or ice-covered altitudes is estimated at 5,500 square miles, seven times that of Switzerland (710 square miles), comparable in size only to the glaciers of the polar regions. The Vatnajökull alone measures 3,300 square miles. The height of the snow line on the southern side of the plateau is 2,000 feet, on the northern side 4,300 feet, the air in the interior being much drier. The appearance of these glaciers is that of the polar regions. The summits of the mountains are covered with flat or vaulted ice fields from which glaciers branch out. The glacier explosions (*jökulhlaup*, glacier leap) are peculiar to Iceland. They occur when there is an eruption of an ice-covered volcano. On such occasions extensive tracts of country are inundated and converted into an eddying current filled with floating ice. Within historical times fjords and bays have in this way been filled up. During the Glacial epoch Iceland was completely overlain with an ice roof or covering of at least 2,500 feet in thickness. Scorings and striations point to more than one glacial period in Iceland. There are many traces of the shifting of the shore in post-Glacial times, especially in the northwest, the highest shore line or raised beach being 250 feet above sea level. There is a double raised beach in the northwest, and the coast is still receding.

On the harborless south and southeast coast people live in little oases, isolated as islands, cut off from the rest of the isle by sand deserts and glaciers, which come to their very door and threaten them perpetually, and under these sleep volcanoes. It is pleasant to find in this howling wilderness oases bright with flowers and fragrant with thyme and meadowsweet. Between the Skaptafellsjökull and the Skeiðarárjökull willows, angelicas, and birches 21 to 22 feet high nestle in clusters, and there is even a mountain ash 30 feet high. All round, every quarter of an hour, is heard the thundering crash of ice blocks falling down on the muddy sands or into the yellow waters of Skeiðará, which changes its bed continually, moving over a mile sometimes often in a day. Nowhere is it possible to study so well

---

[a] *Surtarbrandur* is the Icelandic name for fossilized tree trunks, a convenient name for the whole of the Icelandic lignite strata.

[b] This lignite band has its representative in the island of Mull and County Antrim.—Ed.

the geological conditions prevailing toward the close of the Glacial epoch in Europe.

Iceland is the center of a suboceanic volcanic region, and no region of the earth has an equal title to be called the "Land of Fire." It owes its very existence to volcanic agency continued to-day and may be truly called the abode of subterraneous heat. No spot on the surface of the globe of its extent exhibits marks of fire in such a multitude, in such a variety, and of such a magnitude. None contains an equal number of volcanoes. Nowhere have eruptions of such magnitude occurred. Doctor Thoroddsen has counted 107 volcanoes, 83 of which are a series of low craters or crater chains, 8 are of the Vesuvius shape, and 16 of the Sandwich Islands lava-cone shape. Five thousand square miles of land are covered with lava. The post-Glacial lava alone would cover Denmark with a layer 16 feet in thickness. The largest lava desert is the Ódáðahraun, which covers an area of 1,700 square miles and is from 1,600 to 3,500 feet above sea level. This lava field has been formed by the eruptions of about 20 volcanoes. The cubic capacity of the lava ejected here would make a solid cube, each side of which would measure about 50 miles. The most frequent form of manifestation of volcanic eruption is the formation of a series of low craters, often several miles in length, along lines of cleavage in the crust of the earth. The longest is that of Laki, 20 miles long, containing about 100 craters. Sometimes lava has welled up out of fissures without craters. The largest of these is Eldgjá, north of Mýrdalsjökull, 19 miles long, 434 feet deep in one place 656 feet deep—bottom 468 feet wide. The volcanoes are not, as was formerly supposed, limited to the region of palagonite breccia. On the Faxa-bay are many small volcanoes which have broken through the basalt. About 25 volcanoes have been active in historic times (900–1900). Vesuvius is dwarfed into insignificance, for the lava flood of the last eruption in Iceland, in 1875, has been computed to contain 31,000 millions of cubic feet, while in the largest eruption of Vesuvius on record, that in 1794, only about 730 millions of cubic feet of lava were ejected.

The lava field of the crater chain of Laki covers some 220 square miles, and the lava current flowed 47 miles away from the place of eruption. The longest flow of lava in Iceland is that from the craters of Fiskivötn, 90 miles long. On March 12, 1875, a lava torrent forced its way 620 yards up an incline of 0° 25′. On March 29, 1875, the pumice ashes of Mount Askja were carried over 1,000 miles away to Norway in eleven hours forty minutes, and in another ten hours to Stockholm. The column of ashes rising from Hekla was measured on April 21, 1766, and was found to rise 16,500 feet above the top of the mountain; on February 5, 1846, it rose 14,350 feet. On April 5,

1766, a fragment of basaltic scoria was hurled from Hekla to Vidivellir, a distance of 103 miles.

The geysers have been so much written about that I shall leave them out and treat more in detail of the volcanoes of Iceland. Several new geysers burst out during the earthquakes in 1896, while the well-known Strokkur disappeared, having been in existence one hundred and seven years.

The crater chains and volcanic fissures run in certain directions, and there are at present two lines in active condition. The one runs from southwest to northeast and contains the craters of Reykjanes, the Hekla, and other volcanoes of southern Iceland. The second line runs from south to north and contains the Mývatn and Vatnajökull volcanoes. Hot springs and sulphur mines occupy the same lines, which are also taken by mountain ranges and submarine reefs. Earthquakes run in the same directions.

Eruptions are not so frequent as in the south of Europe. Hekla breaks out at intervals of seventy to eighty years, other volcanoes even less frequently.

Hekla, "The Cloak" (from the shape), the most famous of Icelandic volcanoes, is 32 miles inland from the nearest point of the coast, and situated west of Torfajökull. Its height is 5,108 feet. It is a longitudinally shaped mountain running southwest to northeast, piled up of lava blocks, pumice, and ashes, with snow-filled craters standing in a row on top; it is an intermediate form between Vesuvius and a crater chain. Parallel with it run other mountain ridges of palagonite, breccia, and tufa (1,000 feet to 1,500 feet) studded with craters. The Norwegian mineralogist, A. Helland, counted fourteen craters in a direct line near Hekla northeast to southwest, each with a lava stream of its own. Vast fields of lava extend round Hekla in every direction.

Of Hekla's eruptions eighteen are historically known, without reckoning three or four eruptions from craters in its neighborhood.

The first-known eruption of Hekla took place in 1104, the last in 1875. One of the most violent was the sixth eruption, July 13, A. D. 1300. "The mountain was riven asunder lengthways, and out of this yawning chasm rushed forth columns of fire and streams of lava which ran nearly to the coast, 32 miles away, leaving here and there in the hollows on its course lakes of liquid fire. The crater vomited red-hot lava blocks to an unprecedented height. They cooled suddenly in the air and burst asunder with a thundering crash. * * * A strong southeaster carried the huge clouds of sand and ashes as far as 180 miles from the volcano, so that they lay thick on the ground all that distance. The eruption lasted on unbroken for nearly a year. On December 28 such masses of sand

and ashes were thrown up that, at a distance of 225 miles, high hills and downs were formed by them, and a violent earthquake laid waste the part of the district spared by the earlier eruption." The ashes reached the north of Iceland. The air was darkened. Famine and loss of life followed and houses were shattered by earthquakes.

The tenth eruption, July 25, 1510, was so violent that huge blocks of lava were thrown out of the crater as far as Skálholt, 25 miles distant, and men were killed there by them. In May, 1554, at the time of the eleventh eruption, people were obliged to live in tents for the greater part of the summer on account of frequent earthquakes. The thirteenth eruption took place from January to March, 1597. Loud reports were heard for twelve successive days in the northmost parts of Iceland, and eighteen columns of fire were seen to rise simultaneously from the mountain. The ashes covered about one-half of the island. In the fifteenth eruption which began May 8, 1636, thirteen craters broke out. The sixteenth eruption, in 1693, may be compared to that in 1300, and lasted from Febuary to August. "The earthquake was felt on the high seas, and endangered ships. Clouds of ashes changed day into pitch dark night, but glowing lava streams lit up the darkness with a red glare. Ashes were borne to Norway. The fall of ashes and downpour of rain lasted all the time till Easter. The cattle saved from instantaneous death, having to eat the singed grass under the ashes, suffered from a scorbutic disease, and lost their teeth or perished."

The eighteenth eruption commenced September 2, 1845, and continued for seven months. Halley says the flames were seen in Orkney. The ashes were carried over to the Orkneys and the column of smoke ascending from the crater was found by the mathematician Gunnlögsen to reach a height of 14,000 feet. The lava stream was 80 feet in depth and covered 8 to 9 square miles. It moved on, scooping up hills of sand and earth in its way, the red-hot liquid breaking forth now and then from under the cooled surface with violent crashes. The lava ejected is computed at 14,400 million cubic feet.

The peninsula of Reykjanes is volcanic throughout, containing no less than 300 volcanoes with about 700 craters. The ranges of volcanic peaks, some of which rise to 2,000 feet, run in the same direction as the Hekla Range. They are mostly extinct; six of them have broken out in historical times. A number of volcanic springs and chasms cleft by earthquakes are also found in the peninsula.

Eldeyjar (Fire Isles) or Fuglasker is a cluster of volcanic rocks situate 10 to 12 miles off the southwest point of Reykjanes. Nine eruptions, the earliest in 1211, are known to have taken place in the bottom of the sea near these islets. In 1783, during the Skapta eruption, an island called Nýey (New Isle), about 10 to 16 square miles, appeared near the Eldeyjar, about 150 miles distant from the

seat of the eruption. This island was taken possession of by the Danes. The next year it had disappeared. The Geirfuglasker (or Skerrie of the Great Auk), one of these islands, was reported in 1884 to have sunk into the sea.

Eldborg (Fire burgh, the fortress of fire) is a crater 179 feet high and 636 feet in diameter, in the middle of a flat plain, from which a lava tract, now called Borgarhraun, issued. It is the first crater mentioned in history in a state of eruption (Landnama, about A. D. 900). From afar it looks like an old feudal castle rising in the midst of the plain, with battlements, alone and isolated. It rises gently till within about 80 feet of the summit, when it shapes itself into a steep and precipitous wall of black, glazed lava, crowned with lofty battlements.

Katla or Kötlugjá, in the eastern part of Mýrdalsjökull, is a volcanic chasm covered with ice between the eruptions. It has burst thirteen times, with prodigious inundations, from 894 to 1860. These "glacier leaps" have carried down masses of pulverized lava and alluvial detritus, filling up fjords and bays, altering the coast line and causing the land to encroach upon the sea. The first eruption of Katla (894) laid waste two districts. Ruins of the farms destroyed that year were found at the beginning of the seventeenth century. During its third eruption, in 1245, glacier slips overran Sólheimasandur. The layers of ashes were half a foot thick. In 1311, fifth eruption, fifty-one homesteads were destroyed and a whole district laid waste. In 1625, eighth eruption, ashes fell in Norway, inundations with ice floes, earthquakes, and columns of fire; lightnings lit the darkness of ashes. Pasture land was covered 2 feet deep with pumice. 1660, ninth eruption: Such was the quantity of stones and detritus borne down with the glacier slide that a dry beach was formed where formerly people fished in a depth of 120 feet. The coast line was pushed over 6,000 feet out into the sea. The ice blocks swept a church away and it sailed out to sea in the midst of them. 1721, tenth eruption: The ice blocks of the glacier slip were grounded in a depth of 400 to 500 feet, 13 to 14 miles out at sea; a grassy ridge of land was swept away and in its place was left a polished slab of rock 6,750 square fathoms. The ashes fell so thick that at farms 115 miles distant from the crater light was obscured so as to make the reading of print impossible. 1755, eleventh eruption: Rocks of the size of a house were embedded in ice blocks carried to sea. Fire and water issued from three craters, accompanied with such terrific explosions that people thought the country was being blown up. A hail of burning stones and balls of fire fell. In the night everything seemed on fire and the air was filled with a sulphurous smell; fifty farms were destroyed. The south part of the country was covered with a layer of ashes one-half to 4 feet thick.

The Sólheima Glacier seemed to rise and sink violently. It sometimes seemed to be raised double its height from the ground.

Eruptions of a magnitude unparalleled on earth in historic times took place from a chain of 100 craters, 20 miles long, about the Valley of Varmárdalur, near the sources of the Skapta, to the northeast of Myrdalsjökull. The lava covered an area of 220 square miles, and the volume of lava ejected is estimated by Lyell, in his Principles of Geology, to be equal to that of Mont Blanc. Thoroddsen puts it at 15 million cubic meters. The eruption lasted from June, 1783, to January, 1784. The greatest length of the lava stream, which passes down the channel of the Skaptá and reaches Hnausar in Medalland, is 47 miles, greatest breadth 15 miles; the length of the second lava stream in the channel of Hverfisfljót is over 40 miles, breadth 9 to 10 miles. In places it fills valleys and chasms of a depth up to 600 feet, yet its average depth here is only 20 to 30 feet. It is said that 37 farms were destroyed and 400 people lost their shelter. Famine and scorbutic diseases raged, and animals died in great numbers; 9,336 persons perished, about one-fifth of the population. The loss of horses is reported to have been 28,013, or 77 per cent of all horses in Iceland; that of cattle 11,461, or 53 per cent; and that of sheep 190,488, or 82 per cent. The mass of matter ejected is computed at 50,000 million cubic yards.

Along the borders of Vatnajökull volcanic eruptions have often taken place. Its greatest volcano is Öraefajökull, which has broken out three or four times with formidable glacier slips. In the middle of the fourteenth century—the annals disagree as to the date—the ice covering the top of the mountain rushed down in a violent torrent toward the sea, bearing along with it so much of stones, sand, and detritus that a sheet of water having a depth of 180 feet was changed into a dry, sandy beach. Five fertile districts were totally laid waste. Forty farms and two churches were swept away out to sea, with all that was in them, in a few hours. Pumice and ashes were carried into the north and west of Iceland 200 to 300 miles.

Its third or fourth eruption took place from August 3, 1727, to May 25, 1728, from five to six rifts in the glacier. The people had to camp out, and walked about with tubs on their heads, as the air was filled with burning embers.

The lava desert, Odáðahraun, which is 1,700 square miles in extent, has many craters, mostly unexplored, except those of the Dyngjufjöll, the largest volcano in Iceland, 4,500 feet in height, east of the center of the desert. These mountains inclose a circular valley or crater, Askja (the basket), 25 square miles in area, a vast crater, 17 miles inner, 24 outer circumference—a mountain built up by innumerable lava flows and upheavals to 3,800 feet, or 2,300 feet above Odáðahraun. Its bottom is 3,100 to 3,500 feet above sea level, inclining east-

ward 1° 26′ toward the mouth of the valley which opens into the surrounding lava tracts. Many active craters stud its bottom. An eruption took place here in 1875. In the southeast corner of this valley is a dip 800 feet deep in the ground, in which there is a round, hot lake, having a temperature of 72° F., and 4,000 feet in diameter when it was found in 1876. In 1884 it filled the whole dip and had become 10,000 feet long, but its temperature was only 56° F.

On March 29, 1875, an eruption covered the whole of eastern Iceland with pumice and ashes. The crater from which the eruption proceeded is situated on the northeast edge of the dip, 300 feet in diameter, 150 feet in depth. Its exterior is a slope filled with ashes; its interior is round and perpendicular. It is now a mud caldron, which no longer emits steam, but goes on boiling, in quaint colors, depositing sulphur. Craters in this lake emit steam, with thundering noises, sounding in the far distance like the simultaneous letting off steam from innumerable pipes. Thoroddsen says:

> Nature is here grander and more overawing than in any place in Iceland I have seen. He who once has stood on the edge of this earthdip will never forget the sight.

The steam pressure seems to have converted all the lava in this eruption into pumice and ashes.

Northeast of the Odáðahraun is a mountain range in which the volcano Dyngja, which has given name to the whole group of mountains, is situated. It is 3,600 feet high. The original crater is 1,500 to 1,600 feet in diameter and half filled with lava, from which 12 columns of lava rise. In the midst of these is a crater 4,500 feet in diameter, 600 to 700 feet deep, with a terrific and startling look down. Northwest of this Dyngja is another volcano, also called Dyngja (northern Dyngja).

North of the Dyngjufjöll in the lava tract Myvatns-öraefi (the desert of the Mosquito Lake) an eruption took place in 1875, near Sveinagjá. A rift 9 miles long appeared, along which some crater cones, 70 to 108 feet high, shot up and spread 10,000 cubic feet of lava over the plain.

No spot in Iceland is so crowded with craters, lava formations, solfataras, and hot springs as the neighborhood of Lake Mývatn, especially on its eastern shore. It is so thickly studded with extinct volcanoes and remainders of prehistoric convulsions as to look more like a landscape in the moon than anything else.

Eruptions took place there with short intervals in the years 1724–1730. The chief volcanoes are Krafla and Leirhnúkur (Clay Peak) in a palagonite ridge running from south to north. Of these eruptions those from Leirhnúkur have been the most formidable.

In an eruption of Krafla, May 17, 1724, great masses of volcanic matter issued from an explosive crater called "hell" (Víti), 1,030 feet

in diameter. No lava was ejected. The fame of this volcano is derived from its crater of boiling clay, now a round lake with green cold water. Close to the crater are sulphur and mud springs.[a]

Iceland has another and greater claim to your interest. It is, as William Morris said, the Greece of the North. It produced in the twelfth and thirteenth centuries a literature unparalleled after Rome before the golden age of England and France, in character drawing, in passionate dramatic power, in severe, noble simplicity, in grim humor. All the characters of the Sagas live and move to-day. Every hill and headland and valley in the island is full of their presence. The Icelander of to-day knows them by heart. It is as if every Englishman, from pauper to king, knew Shakespeare's historical plays and could retell them more or less in his or her own words. It has kept the national pride alive through evil times. It has preserved the language almost untouched by time and foreign intercourse.

Nowhere is the contrast between man and his surroundings so glaring as in Iceland. Buried in snow and darkness, deprived of every comfort, living on rancid butter and dried fish, drinking sour whey and milk, dressed like his servants, seeking in a little boat his food, yet a cultured mind, possessing an intimate knowledge, not only of the history of his own country but of Greece and Rome, a poet fond of throwing off satires, intellectually and morally the equal of his European guest, considering himself your equal and refusing to be ordered about by a rich Englishman, owner of several square miles of land and hundreds of sheep, with a pedigree going farther back than that of his visitor, a jack-of-all-trades, a blacksmith in his smithy, boat builder and carpenter, an artist in filigree work, a carver in wood, an eager reader of books. He has universal education up to the degree to which it is useful for a man. There are no schools in Iceland, yet every child at 12 can read, according to the parish statistics. In no country in Europe are so many books printed and sold, in proportion to the population. A population equal to that of Hampstead, 76,000, has 12 printing presses, the earliest being established as far back as 1530. About 100 books annually, 14 newspapers, and 8 periodicals are produced to satisfy the literary needs of this little nation.

Yet this literary people still live in a pastoral and Homeric civilization which is a modern lesson of the healthfulness of human life lived in close contact with the free, wild life of nature, such as would have delighted the heart of Rousseau or Thoreau. As a proof that this life is healthy I give the example of a clergyman who died four years ago, 113 years old, having managed to live all his days healthy

[a] Mr. Stefanson gives in his article a tabulated statement, here omitted, of eruptions of the volcanoes of Iceland from about the year 900 to 1728.

and happy on £30 a year, the average stipend in the Icelandic church. The sheep yield food and clothing. Their wool is pulled off in spring, carded, spun, woven in hand looms, and worn undyed. You make shoes of their skin and spoons of the horns. Every opportunity is seized for the telling of stories and reciting of poems. Only the milk ewes are kept at home in summer to be milked, the rest of the sheep are gathered in from the mountains in autumn, notice being given at church from the pulpit. These autumn gatherings, with people sitting on the walls of the stone inclosure telling stories, are quite Homeric. The winter evenings with each member of the family busy at work in the same room; the men shaving the wool off sheepskins on their knees, making ropes and nets of hair, the women using spindle and distaff, embroidering, etc., afford a still better opportunity for stories and poems.

There are even wandering minstrels who gain their livelihood by reciting prose or poetry, which they know by heart, at various farmhouses till they exhaust their stock.

To conclude with a few statistics, the annual trade of Iceland is worth close on £1,000,000, export and import together. The principal articles of export are salted codfish, wool, mutton, and eiderdown. A large and increasing part of the trade is with Great Britain. In the fifteenth century all the foreign trade was in English hands. Henry VIII negotiated with Denmark in 1518 and 1535 for its transfer to England, and its economic and strategic importance to Great Britain has been set forth as late as 1835 in the Quarterly Review by Sir George Mackenzie and Sir William Hooker, who held that Iceland ought to be a British possession. It has been declared by experts that the fishing grounds of Iceland are richer than those of Newfoundland, and, though they are much nearer Great Britain, their annual yield is not more than £2,000,000, because they are not worked as they ought to be.

For close on four hundred years Iceland was an aristocratic republic, ruled by the great families of the early settlers, among whom was a Norse queen of Dublin. A fourteen days' open-air Parliament of all Iceland met annually in June at Thingvellir, and the speaker of the law (lög-söguman) used to recite from memory the whole of the unwritten, elaborate code of laws of the country to the assembly. In 1262–1264 Iceland was united to Norway, and in 1380 with Norway to Denmark. The Danish rule ruined the island, economically, but since the granting of self-government and the reestablishment of the old Parliament in 1874, at Reykjavik, great progress has been made. The revenue of Iceland is now six times as large as twenty-eight years ago, and it is probably the only country with no debt, but with 1,000,000 crowns of savings in its exchequer. Yet

more has been expended on the ways and roads of the island since 1874 than in all the centuries down to that date. The Icelanders are keen politicians. Women have been in possession of the municipal vote earlier in Iceland than in any other country, and they do not change their names when they marry. The Parliament (Althing) is composed of an upper house of 12 members and a lower house of 24. A minister for Iceland is to reside at Reykjavik in place of the governor, who at present is the highest official in the island and forms the link between the Crown at Copenhagen and Parliament at Reykjavik.

The Icelanders are a religious and God-fearing people, but very averse to parsons' rule. It is a habit to criticise the sermon when you shake hands with the clergyman after the service. There is little crime. It is lawful for a farmer to steal his neighbor's hay when his cattle refuse to eat his own hay, and for this stolen food the cattle are said invariably to find an excellent appetite.

II.

The earliest inhabitants of Iceland in historical times were Celts, who called the island *Thule* (Thyle, Thile). The Greek traveler, Pytheas of Massilia, made voyages of discovery in the northwest of Europe in 330–320 B. C. He relates that he had found the northmost country of the world, "Ultima Thule," of which he gave a somewhat fantastic description. We only know of this discovery of Pytheas through the quotations of the Greek geographer, Strabo, and other ancient writers. Strabo himself seems to have got his knowledge of it not from Pytheas, but indirectly through the historian Polybius. Yet it is possible that Strabo may have seen Pytheas's own account, which, however, has been lost. All descriptions and accounts of Ultima Thule found in writers before A. D. 825 are indirectly derived from Pytheas as a primary source. It is true that Bede (died A. D. 735) mentions Thule three times in his writings, and his description of its site is suitable to Iceland, but he may have taken his account from Plinius, who, again, derived his from Pytheas. It is more probable that Bede heard of Iceland from monks in the British Isles who had been there.

The first undoubted account of the discovery of Iceland is found in Chapter VII of De Mensura Orbis Terræ, by the Irish monk Dicuil, written in A. D. 825. He stated that thirty years ago—i. e., 795—some monks told him of their stay in Iceland. There is nothing in the passage to show that the island had not been discovered long before 795 or that it was only visited by monks; on the contrary, for Dicuil says it is untrue what others say that the sea around Iceland is frozen, etc.

Dicuil thinks this island is Pytheas's Thule, and this seems to have been the name given to the island when it was discovered by the Celts. We may, then, take it for certain that Iceland was called Thule by its earliest inhabitants.

The Norwegian heathen settlers who followed in the latter half of the ninth century found books, bells, and croziers left behind by the monks who fled from the island at the approach of the vikings; but these and a few place names, such as Papey, Papyli, Papos, are the only traces left of these early settlers. They were called "Papar" by the vikings.

It is doubtful whether Naddoð or Gardar was the first Scandinavian discoverer of Iceland, about A. D. 860. Raven-Floki, who let loose three ravens in mid-ocean and sailed in the direction in which they flew, was the next to go there, and called it Iceland, because from a mountain top in northwest Iceland he saw a fiord full of drift ice. The first Norwegian settler in Iceland was Ingolf Arnarson, a chieftain, in A. D. 874. When in sight of land he threw the pillars of his own high seat overboard and settled where they came ashore, on the advice of his gods, as he believed. When, after the battle of Hafursfiord, 872, Harold Fairhair became undisputed King of all Norway and subjected the free chieftains and noblemen of the country to taxation, they preferred to emigrate. For sixty years the men of the best blood in Norway flocked to Iceland. Each chieftain took with him earth from below his temple altar in the motherland, built a new temple in the new country, and took possession of land by going round it with a burning brand in his hand. He deposited on the altar the holy gold ring which he was to wear at all ceremonies. Until a Parliament for Iceland was established in 930 these chieftains were the rulers of the island, each in his district or land-take (land-nám), as it was called.

PERIODS OF ICELANDIC HISTORY.

I. The Commonwealth, A. D. 870–1264. The Eddas. The Sagas.

II. The Norwegian time, A. D. 1264–1400. Copyists and annalists.

III. The English period, English influence being paramount, A. D. 1413–1520.

IV. The Reformation, the sixteenth century.

V. The Renaissance, the seventeenth century.

VI. The Stagnation, the eighteenth century.

VII. The Independence Movement and its victory, 1830–1905.

Few Englishmen are aware that there is a British colony in the Atlantic which has never owed allegiance to the British Empire,

which was a republic for about four centuries and during that time produced one of the great literatures of the world, which is larger in area than Ireland by one-fifth, and which is only 450 miles distant from the nearest point of the northwest coast of Scotland, Cape Wrath. This is Iceland, fully one-half of whose settlers, in the ninth and tenth centuries, came from the northern parts of the British Isles—Scotland, Ireland, the Hebrides, and Orkney—and were partly Norse and partly Gaelic in blood.

Fewer still are aware that the long constitutional struggle of Iceland is at an end, Denmark having conceded all its demands. To understand the present stage of this question it is necessary to tell the history of the past.

Iceland was settled and colonized in the years 870–930, partly by Norwegian chieftains who left Norway because they would not submit to King Harold Fairhair, and partly by the kinsmen of these chieftains and by others from the northern parts of the British Isles. We possess the record and genealogy of about 5,000 of the most prominent of them in the *Landnámabóc*, or Book of Settlement. No other nation possesses a similar full record of its beginnings.

A republic or commonwealth, with a constitution and an elaborate code of laws, was established and lasted till A. D. 1262–1264, four centuries if reckoned from the settlement—the longest-lived of republics, Rome alone excepted.

The chieftains, goðis, who presided not only at meetings but at temple feasts and sacrifices, and were thus the temporal and spiritual heads of their dependents, sent Ulfliot to Norway to inquire into the laws and make a constitution for Iceland. He accomplished it in three years. According to this, in 930, a central Parliament for all Iceland, the Althing, was established at Thingvellir, in southwest Iceland, and a "law speaker" was appointed to "speak the law." In 964 the number of chieftaincies, goðrðs, was fixed at 39, 9 for each of the four quarters into which the island was divided, except the north quarter, which was allowed 12. The Althing, as a court of appeal, acted through four courts, one for each quarter. There was also a fifth court, instituted in A. D. 1004, which exercised jurisdiction in cases where the other courts failed. For legislative purposes the Althing acted through a committee of 144 men, only one-third of whom, viz, the 39 goðis and their 9 nominees, had the right to vote. The 9 nominees were chosen by the goðis of the south, west, and east quarters, three by each quarter, to give each of these quarters the same number of men in the committee as the north quarter had. Each of these 48 men then appointed two assessors to advise him, one to sit behind him, the other to sit in front of him, so that he could readily seek their advice. Thus the committee of

144 was made up, and it was called "*lögrétta*" (amending of the law).

After the introduction of Christianity, in A. D. 1000, the two bishops were added to the lögrétta, while the sole official of the Republic, the law speaker, used to preside. It was his duty to recite aloud in the hearing of all present at the Parliament the whole law of Iceland, going through it, in the three years during which he held office, at the annual meeting in the latter half of June, which generally lasted a fortnight; also to recite once a year the formulas of actions at law—all from memory, for no laws were written down till about 1117. When any question of law was in dispute, reference was made to him, and his decision was accepted as final. For his labors he received an annual salary of 200 ells of vadmal (woolen cloth) and one-half of the fines imposed at the Althing. He was the living voice of the law (*viva vox juris*), but he was neither judge nor magistrate, and did not open the Althing or take the responsibility for keeping order at it, for that was done by the goði, within whose jurisdiction the Althing met. He enunciated the unwritten law, accepted by all.

The goðis and their nine nominees sat on the four middle benches, arranged round a central square, twelve on each, while the two assessors of each of them sat, one on the bench behind, the other on the bench in front of him. The lögrétta made, modified, and applied the laws. Decisions were carried by simple majority, though the minority must not consist of more than twelve members. If a resolution of the lögrétta infringed the rights and interests of any freeman, he could veto or suspend it by appearing in person. It was one of the numerous precautions taken to guard the ancient palladium of personal liberty. It was a counterpoise to the abuse of oligarchy. The whole nation, through any of its members, had, in the last instance, the right to take part in the deliberations of the Althing.

The lögrétta published and interpreted the laws through the law speaker. He could be consulted at any time of the year on a point of law, being its official interpreter. If a law was passed by in silence and not recited publicly by him for three years—i. e., for his term of office—it was abolished, provided that no remonstrance was made. The only trace there was of central power in the island resided in him, but as he had no executive power it was next to none.

After the Althing the new laws and other matters of public importance were proclaimed at a "thing," held in each "thing" district of Iceland, and called "leið." There was another "thing" held in the spring, dealing with local matters and preparing for the Althing.

The source of the English trial by jury is the Icelandic kvið, and the English juries de vicineto in the thirteenth century correspond with that form of trial.

At the Althing of A. D. 1000 a debate took place about the introduction of Christianity. The Christian chieftains supported the envoys of King Olaf Tryggvason, of Norway, and the heathens, to avoid civil war, agreed to submit it to the decision of the heathen law speaker, Thorgeir, whether the Christian religion or the old faith should prevail in Iceland. For three days and three nights he lay quietly in his tent thinking over the two religions. On the fourth day he stood forth on the law mount, or hill, and declared that they were to be baptized and call themselves Christians, the temples to be destroyed, but those who liked to sacrifice at home to the old gods might continue to do so, and a few heathen customs were to be permitted. The people accepted this: only the men from north and east Iceland refused to be immersed (baptized) in cold water, so the hot springs at Reykir were used for the rite.

Two bishops' sees were established, at Skáholt in 1056 and at Hólar in 1106, subject successively to the metropolitan sees of Bremen, Lund, and Thrandheim. The bishops were elected at the Althing until the archbishop of Thrandheim appointed Norwegians in 1237. Two bishops, St. Thorlac and St. John, were by a public vote at the Althing declared to be saints, after a thorough and searching inquiry into the miracles they had wrought. Thus the Icelandic Church was a church of the people for the people, and Rome had little power in the island. Celibacy was never accepted by it. In the twelfth and thirteenth centuries six Benedictine and five Augustinian cloisters were founded, all centers of learning and culture. The greater part of the Icelandic Sagas is supposed to have been written or at least copied in them. The oldest was the Benedictine cloister at Thingeyrar, 1133; next, Thverá, 1155, also Benedictine. The Icelandic monks wrote in Icelandic, not in Latin, as all their brethren on the Continent did. They were intensely national and handed down with scrupulous care even the records of the heathen faith. But it was owing to disputes about the jurisdiction of the clergy that the King and archbishop of Norway were able to set chieftain against chieftain and undermine the Icelandic commonwealth, disputes similar to those which Thomas à Becket, of Canterbury, carried on with Henry II half a century earlier, and which are recorded in the Icelandic Thomas Saga.

The two centuries and a half which followed the introduction of Christianity were the greatest period in the history of Iceland. A great literature, especially the Sagas, came into being, while the Continent, with the single exception of the Provencal Troubadours, had nothing better to show than monkish annalists. At the courts of Norway, Denmark, Sweden, Dublin, England, and Orkney, Icelandic poets were the chief or, usually, the only singers of heroic deeds. It

was an outburst of literature such as the world had not seen since the downfall of Rome.

By degrees the chieftaincies, goðorðs, which passed not only by inheritance, but also by gift or sale, came into the hands of a few great families. In consequence some chiefs became masters of large districts, and, like feudal lords, rode to the Althing with an armed body of retainers, numbered by hundreds. The old blood feuds became little wars conducted by armies that engaged in battles. Disputes about the jurisdiction of the church provoked interference by the Metropolitan See of Drontheim, which appointed the two Icelandic bishops of Hólar and Skálholt. Internecine civil wars, lasting through the first half of the thirteenth century, exterminated some of the great families who had monopolized the chieftaincies. The Wars of the Roses in England (1465–1485) are a close parallel to these wars in Iceland.

The kings of Norway had always held that the Icelanders, as Norwegian colonists, ought to own their supremacy. Olaf Tryggvason and St. Olaf had in vain labored to win the Icelanders over to this view. King Hákon Hákonson (1217–1263) now suborned chief against chief. The great house of the Sturlungs had perished at the battle of Orlygsstad, 1238, and Snorri Sturluson, the greatest historian and writer that Iceland has produced, was murdered at Reykjaholt in 1241 at the King's instigation. The one leading man of the family left alive, Thord Kakali, was called away to Norway. By bribes, by persuasion, by sending Icelandic emissaries through the island, by winning over the most powerful chief in Iceland, Gizur Thorvaldsson, it came about that the Icelanders, of their own free will, in solemn parliament, made a treaty of union with the King of Norway in which they accepted his supremacy; the south, west, and north quarters at midsummer 1262, one year before the battle of Largs, when Norway lost her colonies in the west; the powerful family of the Oddaverjar in 1263, and the east quarter in 1264, the date of the summoning of the first Parliament of England by Simon de Montfort.

The treaty of union, as passed by the Althing, enacted that a jarl should represent the King of Norway in Iceland; that the Icelanders should keep their own laws and keep the power of taxation in their hands; that they should have all the same rights as Norwegians in Norway; that at least six trading ships should sail from Norway to Iceland annually; that "if this treaty, in the estimation of the best men (in Iceland) is broken, the Icelanders shall be free of all obligations toward the King of Norway." This treaty is the Magna Charta, the charter of liberty of Iceland. It has sometimes been in abeyance, but has never been abolished. It has sometimes been dis-

regarded by Denmark, when it wished to make Iceland a Danish province, but the people of Iceland have always taken a firm stand upon it.

There never was more than one jarl in Iceland, Gizur Thorvaldsson, who died in 1268. The old code of laws, Grágás, elaborate as the Codex Justinianus, and going beyond it, e. g., in the mutual insurance of each commune against fire and against loss of cattle, was replaced in 1271 by a Norwegian code, the Ironside, Járnsiðá. Two law men (lögmenn) were to govern the country, and the Lögrétta was limited to its judicial functions. The Althing refused to accept the new code, though it was brought from Norway by the greatest author of the latter half of the thirteenth century, Sturla Thordarson. A new code, Jónsbók, which was a compromise code brought by the law man, Jón Einarsson, to Iceland in 1280, was accepted at the Althing of 1281, with some alterations. It is called "Jónsbók," after Jón Einarsson, and is still, in parts, the law of Iceland.

Iceland was divided into "syslas," or counties, administered by sheriffs (syslumenn) appointed by the King, and the place of the local "things" was taken by bailiffs (hreppstjóris), mainly concerned with the poor law and tax gathering. The estates of the Sturlung family were confiscated by the King. Trade languished, and the black death, in conjunction with great volcanic eruptions, brought Iceland to the verge of ruin. As soon as Norway became united with Denmark through marriage in 1380, the treaty of union was more or less disregarded, and the Icelanders were so broken in spirit that they meekly submitted.

The fifteenth century is looked upon as the darkest age of Icelandic history. Denmark confined all Iceland trade to the one port of Bergen, in Norway, and the English trade with Iceland, which began about 1412, was carried on in defiance of edicts from Copenhagen. Soon the English buccaneers took the law into their own hands and arrested all Danish and Norwegian officials who tried to prevent their trade. The Icelanders seem to have taken the English side in these quarrels, and about 1430 the two bishops of Iceland were each Englishmen. At one time Iceland was actually held by the English who built a fort in the south of the island. A number of English words came into the Icelandic language, and are in it to-day. By favoring the Hanseatic traders, Denmark finally succeeded in ousting English trade from Iceland, but the English fishing fleet, the so-called "Iceland Fleet," continued to fish for cod and ling on the shores of Iceland during the whole of the sixteenth century. As late as 1593 fifty-five ships sailed for Iceland from Essex, Suffolk, and Norfolk alone for this purpose. Henry VIII negotiated with Denmark in 1518 and 1535 about the transfer of Iceland, the interests of England

in that island being of great importance. The House of Commons, in one of its petitions to the King, states that the realm will be undone unless the fish supply from Iceland is regular. Both Henry VIII and Elizabeth had Iceland fish on their table at least twice a week, and special commissioners selected the best fish out of every ship on its return from Iceland for the court.

The Reformation came to Iceland about the middle of the sixteenth century, and was resisted by the Bishop of Hólar, Jon Arason, a well-known poet and popular leader. At last he was taken prisoner in a battle and publicly executed, with his two sons, in 1550. Thus the Reformation was forced by the Crown on an unwilling people. The New Testament in Icelandic came out at Hólar in 1584. The woodcuts and some of the font of type of this fine work were made by Bishop Gudbrand Thorlaksson with his own hands. The translation of the Old Testament was also made by him.

The printing press woke the national spirit. Arngrimur Jonsson at the end of the sixteenth century rediscovered the treasures of the past and brought them to the knowledge of Europe in his Latin writings. His Brevis Commentarius in 1593 and his Crymogaea in 1609 were known and partly translated all over Europe. It was at the beginning of the Renaissance of Old Icelandic literature. The learned Thormod Torfaeus (1636–1719), an Icelander who was the historiographer of the King of Denmark, continued Arngrim's work. The Icelandic antiquarian, Arni Magnusson (died 1730), diligently rescued every scrap of old manuscript to be found in Iceland, and founded the magnificent Arna-Magnaean collection in Copenhagen, devoting all his life and money to it. It is due to him more than to any one man that the old literature of Iceland has been preserved.

The Hanseatic trade was succeeded by a Danish monopoly of trade, which completed the economic ruin of Iceland. Algerine pirates appeared off the coast and carried off hundreds of people into slavery in 1627. Smallpox caused the death of one-third of the population in 1707, a famine raged in 1759, and the volcanic eruptions of 1765 and 1783 laid waste large tracts of the island. Nature seemed in league with man to render Iceland uninhabitable.

During the war between England and Denmark, 1807–1814, English privateers prevented Danish ships from reaching Iceland, and a famine would have resulted if Sir Joseph Banks, who had visited Iceland in 1772, had not by an order in council got Iceland specially exempted from the war.

The national movements in Europe in the first half of the nineteenth century reached the shores of Iceland, and a band of patriots began a political struggle to win back the old freedom. On March 8,

1843, a deliberative council was established in Iceland, and when Denmark had got her own free constitution, a national assembly, a "constituante" met in July, 1851, at Reykjavik. Denmark proposed to extend her constitution to Iceland, which was to send six members of Parliament to Copenhagen. But a committee, under the leadership of Jon Sigurdsson, who was equally eminent as historian, antiquarian, and politician, declared that as Iceland, by the treaty of union in 1262, entered of her own free will into union with the Crown, on certain conditions, she claimed, not provincial independence as proposed by Denmark, but a sovereign status, taxation, a high court, ministers in Iceland responsible to the Althing; in short, personal union. The constituent assembly was dissolved or dispersed with threats of military interference, but this constitutional struggle went on under the leadership of Jon Sigurdsson, until the King of Denmark came to Iceland in 1874 with a constitution which was a compromise. From 1874 to 1900 more than fifty bills passed by the Althing were vetoed at Copenhagen, where the Danish minister of justice was simultaneously minister for Iceland. At last, in 1902, a new liberal government at the Danish capital conceded all the demands of Iceland. An Icelandic minister for Iceland now resides at Reykjavik, solely responsible to the Althing. The King can veto a bill only on his advice.

Thus the geographical isolation of Iceland, instead of relegating her to oblivion, has given her an opportunity to play a part on the stage of history as an asylum for the old institutions, faith, and customs of the Teutonic race. With the language of the tenth century unaltered, it is to-day a living Pompeii where the northern races can read their past.

THE RECENTLY DISCOVERED TERTIARY VERTEBRATA OF EGYPT.[a]

By C. W. Andrews, D. Sc., F. R. S.
British Museum (Natural History).

As in most branches of science, the growth of our knowledge of the fossil vertebrates of the world takes place, as a rule, by the slow accumulation of isolated facts; but occasionally some fortunate discovery not only leads to the bridging over of long-recognized gaps, but also throws much light on points the significance of which was previously obscure. The discovery that the remains of vertebrates are comparatively common at several horizons in the Tertiary formations of Egypt was such a happy chance, and has resulted in the solution of several long-outstanding problems.

Until within the last few years the paleontological history of Africa, so far, at least, as the mammalia were concerned, was an almost complete blank. It is true that so long ago as 1875 Owen described the occurrence of a primitive Sirenian in the Middle Eocene of the Mokattam Hills, near Cairo, and a few years later Schweinfurth discovered bones of Zeuglodonts in the Middle Eocene deposits of the Fayûm; but in both instances the animals in question are of aquatic habits, and therefore throw no light on the mammalian fauna of the Ethiopian land mass that must have existed throughout Tertiary, and probably also Secondary, times.

The highest horizon in the Egyptian Tertiary beds at which vertebrate remains are found is the Middle Pliocene, beds of this age occurring in the Wadi Natrun, a depression in the Libyan desert some 60 miles from Cairo. From this locality collections have been made by Captain Lyons and Mr. Beadnell, and also by Doctors Stromer and Blanckenhorn. They have been described by Doctor Stromer and the present writer. The chief mammals recorded are *Hipparion*, *Hippopotamus*, *Libytherium* or *Samotherium*, and *Mastodon*, as well as carnivora, including a saber-toothed tiger and members of the Canidæ, Lutrinæ, and Phocidæ. The next bone-bearing

[a] Reprinted, by permission, with author's corrections, from Science Progress in the Twentieth Century, No. 4, April, 1907. London, John Murray.

horizon is the Lower Miocene, fluvio-marine beds of this age at Mogara, about 150 miles west of Cairo, and the Wadi Faregh, nearer the Nile Valley, having yielded a number of interesting forms. Of these, *Brachyodus africanus*, an animal closely allied to *Hyopotamus*, bones of which are common in the Oligocene beds of the Isle of Wight, was discovered in 1898 by Doctor Blanckenhorn, and seems to be the first Tertiary land mammal recorded from Egypt. Later, Mogara was visited by Mr. Beadnell and the late Mr. Barron, who was accompanied by the present writer. Many specimens were collected, including remains of a rhinoceros, and also of a proboscidean, closely allied to, if not identical with, *Tetrabelodon angustidens*, from beds of similar age in Europe.

Although the mammals and other vertebrates found in the beds above referred to are of considerable interest, they are only such as might have been found in any European deposits of similar age, and afford no clue to the real autochthonous mammalian fauna of the Ethiopian region; in fact, it is only in the Middle and Upper Eocene beds of the Fayûm that we find remains of animals that can be regarded as representing that fauna. Considering the importance of these fossils, it is proposed to give a brief account of their discovery, of the locality in which they are found, and, finally, of the more important forms represented in the collections which have been made up to the present.

The first remains of land mammals from this locality were collected in 1901. In that year the present writer had the privilege of visiting the district with Mr. Beadnell, of the Egyptian survey, who was engaged in mapping this area. On this occasion remains of marine animals, including a Sirenian (*Eosiren*) and large snakes (*Gigantophis* and *Pterosphenus*), were collected, accompanied by traces of an ungulate, to which the name *Moritherium* was afterwards given. These seemed to be of such interest that a further visit was made, resulting in the discovery of many new forms, including *Barytherium* from the Middle Eocene, and *Palæomastodon* from the Upper Eocene. Toward the end of the same year Mr. Beadnell discovered remains of an extraordinary ungulate, to which he gave the name *Arsinoitherium*, and he also obtained portions of the skeleton of several other new forms. Since then the locality has been visited on several occasions by Mr. Beadnell on behalf of the Egyptian geological survey, and by the writer for the British Museum. The large collections made on these occasions have been described and figured in the Catalogue of the Tertiary Vertebrata of the Fayûm, published last year.

The Fayûm is a province of Egypt lying about 60 miles south of Cairo, to the west of the Nile Valley, from which it is separated by a strip of desert traversed by a canal, through which practically the

whole water supply of the district passes. It consists mainly of a depression in the desert, the lowest portion being occupied by a large lake of brackish water—the Birket-el-Qurun—which is, in fact, the remnant of the much larger body of water described by Herodotus under the name Lake Mœris. From early historic times, for various reasons, this lake has been decreasing in size, and there are to-day numerous evidences of its former extent, such as traces of the old shore lines marked by stumps of tamarisk bushes, which then, as now, fringed its margin; but still more eloquent witnesses of its former size are the ruined towns and temples now lying in the desert far from any water supply. To the north of the lake the land rises in a succession of escarpments separated by plains of varying width to a height of about 340 meters above the sea; the surface of the lake itself is about 44 meters below the level of the Mediterranean. The lower escarpments are carved in beds of Middle Eocene age, the higher in the Upper Eocene, the actual summit of the escarpments being formed by the outcrop of a sheet of interbedded basalt, above which are the gravelly fluvio-marine Oligocene beds which form the undulating surface of the high desert stretching away toward the north.

The vertebrate remains are found some distance to the north and west of the lake, and they occur at several horizons, the lowest being near the bottom of the Middle Eocene. At this horizon the beds are almost exclusively marine, and the only vertebrates found are aquatic types, the most interesting being a primitive toothed whale *Prozeuglodon*. The next bone-bearing beds are at the top of the Middle Eocene, and consist of a series of marine and estuarine deposits, which contain the remains of both marine and terrestrial mammals, the most important of the latter being *Mœritherium*, the earliest known Proboscidean, and *Barytherium*, a remarkable ungulate of which the affinities are uncertain. It is, however, from the Upper Eocene fluviatile beds that by far the greater number of forms have been obtained. These beds are obviously the deposits of a great river, probably flowing from the southwest, and carrying down in its floods the carcasses of drowned animals inhabiting its banks, together with vast numbers of tree trunks which to-day, in a silicified state, are strewn over the plains formed by the dip slopes of these beds. This series of fluviatile beds seems to have continued with some interruptions throughout the Oligocene and Miocene periods, continuing probably till well on in the Pliocene; and it is from such deposits at Mogara and the Wadi Natrun that the Miocene and Pliocene faunas above referred to are derived. In fact, the conditions seem so favorable to the preservation of vertebrate remains that it is almost certain that only further exploration of the region to the north of the Fayûm depression is necessary to lead to the discovery of faunas at other horizons. If this should prove to be the case, then it seems

certain that in Northern Africa we shall have a succession of mammalian types second in interest only to the wonderful series found in North America.

A brief account of some of the more important of the fossil vertebrata, more especially the mammals, at present known from the Fayûm, may now be given. In the first place, it should be noted that in addition to early forms of groups already known several entirely peculiar types of mammalian life have been found. Amongst these the most important are *Arsinoitherium*, which has been regarded as representing a new order of mammalia, most nearly allied to the Hyracoidea, and *Barytherium*, which not improbably may also represent a new subordinal group, but of which the affinities are at present quite uncertain.

Arsinoitherium is one of those extremely peculiar types which, as in so many other instances, shows by its extreme specialization in certain directions that loss of adaptability to new conditions of life which almost inevitably leads to extinction. Many similar instances might be quoted, one of the most notable being the Titanotheriidæ of North America. In its general appearance *Arsinoitherium* must have much resembled a large rhinoceros, but instead of having one or two horns in the median line it not only possessed a pair of small horns situated over the orbits, but also a pair of enormous nasal horns, both pairs, unlike the horns of *Rhinoceros*, being formed by bony outgrowths of the skull that were probably covered with a horny sheath during life. The posterior surface of the skull slopes forward, and is deeply hollowed for the attachment of the powerful muscles necessary to support the heavy head. The front of the snout is narrow and pointed, a circumstance which, coupled with the character of the incisor teeth, makes it at least probable that the animal did not graze, but browsed on bushes and low herbage, most likely with the assistance of a mobile upper lip, like the black rhinoceros of to-day. The teeth were of very peculiar structure. The dentition is complete, and forms on either side of the jaw a closed series, the crowns of all the teeth wearing to a common level, with the exception of the anterior upper incisors which form slight hook-like projections, and no doubt helped in seizing the food. All the teeth are high-crowned, the molars especially so, and it is further remarkable that the upper molars differ entirely from the premolars in form. The type of molar structure here found is quite unknown elsewhere, but it may have been derived from the deepening of the crowns of molars like those of *Hyrax*, though some writers are inclined to regard it as a specialization of the type found in *Coryphodon* and other primitive Amblypoda.

The limbs were short and massive, and the feet were much like those of the elephant, all five toes being retained. At the same time

this resemblance with the elephant, in the hind feet at least, is only superficial, the actual arrangement of the tarsal bones being widely different. As remarked above, the affinities of this remarkable creature are uncertain, and it was considered necessary to establish a new subdivision of the Ungulata for its reception, though at the same time relationships with the Hyracoidea were pointed out. Winge, on the other hand, in a recently published memoir on the Ungulata, boldly refers it to the Hyracoidea. Probably its real position will remain doubtful till some earlier and less specialized members of the same stock have been discovered.

Barytherium, from the Middle Eocene beds, is another large and heavily built ungulate, of which unfortunately very little is yet known. Only the upper and lower jaws, with the cheek teeth, and a few limb bones have yet been found. All are characterized by their immensely massive construction. The teeth have comparatively low crowns, with two transverse ridges. The humerus has all its ridges and processes for the attachment of muscle greatly developed, indicating a fore limb of great strength, and, judging from its form, possibly employed in digging. The relationships of this creature are unknown; it is by some regarded as belonging to the Proboscidea, and it has even been suggested that there may be some relationship with the South American Pyrotheria.

Although *Arisinoitherium* and *Barytherium* are interesting for the peculiarities they present, their very isolation detracts considerably from their importance, for they throw no light on the earlier history of any of the previously known groups of mammals. From this point of view the remains of primitive Proboscideans from these Egyptian deposits are of vastly greater interest, for they at once settle the point of origin of the group and carry back the line to a generalized type of ungulate showing only the beginning of the extraordinary specializations characteristic of the later forms. Previous to the discovery of these Egyptian forms, the earliest Proboscideans known were species of *Tetrabelodon* and *Dinotherium* from the lowest Miocene beds of Europe, where they appear suddenly at this horizon, no trace of any related form being found in the earlier Tertiary deposits of that continent. The sudden appearance in the European fauna of these and members of some other groups led to a number of speculations as to where these animals had originated. Osborn, Stehlin, and Tullberg for various reasons all came to the conclusion that the evidence pointed to the existence of an Ethiopian land area in early Tertiary times and they considered that not only the Proboscidea, but several other groups—notably the Sirenia, Hyracoidea, certain Edentates, the Antelopes and Giraffes, the Hippopotami, several divisions of the Rodentia, and lastly the Anthropoidea—originated in that region. Of many of these the early

forms have still to be found, but the predictions of the above writers have already been fulfilled in the case of the Proboscidea, the Sirenia, and the Hyracoidea, so that there is good reason to hope that ancestral forms of some of the other groups will yet be discovered in northern Africa.

The earliest Proboscidean yet known is *Mœritherium*, remains of which are found in the Middle and Upper Eocene. This animal was about the size of a tapir, which, moreover, it must have much resembled in general appearance. The skull presents none of the striking peculiarities of the later Proboscidean skull, though traces of the beginnings of some of these characters can be seen. Thus, the nares are already a little removed from the front of the snout, and the nasal bones are small; again, the bones of the occipital region are somewhat swollen by the development of cellular tissue in their interior, a development that reaches enormous dimensions in the modern elephants. In the upper jaw all the teeth of the full Eutherian dentition are present, with the exception of the front premolars. The second incisors are much larger than the others and form downwardly directed tusks, the beginning of the great tusks of the later types. The premolars are all simpler than the molars, the low crowns of which bear two transverse ridges, each ridge being formed by the fusion of two tubercles, so that in fact the teeth may almost be said to be quadrituberculate—a very primitive condition. The anterior portion of the mandible is spout-like and bears two pairs of incisors, which project forward. Of these the inner pair are small, while the outer are enlarged, and become the lower tusks of later forms. The canine is lost. The description of the upper-cheek teeth given above applies equally well to the lower, except that, as usual, the last lower molar has a third lobe or heel. The skeleton is imperfectly known, but it is certain that the neck was relatively long, so that the animal could reach the ground with its mouth in the usual way. The limb bones, so far as known, are practically those of a diminutive elephant. In this animal, therefore, we have a comparatively generalized type, but at the same time some of the characters which developed to such an extraordinary extent in later forms are already recognizable. Such are the transverse ridging of the teeth, the enlargement of one pair of incisors to form tusks, the beginning of the shifting back of the narial opening, owing to the development of a short proboscis and the commencement of the inflation of the bones at the back of the skull.

Although remains of *Mœritherium* are first found in the Middle Eocene beds, it persisted till the Upper Eocene period; but there it is accompanied by an animal, *Palæomastodon*, which shows a considerable advance toward the later proboscidean type. Probably *Mœritherium* still continued to inhabit the swamps, while *Palæomas-*

todon represents a form becoming adapted to existence on dry ground. Although referred either to *Mæritherium* or *Palæomastodon*, several forms, intermediate both in size and in some other respects between these two genera, are known to have existed, but the remains by which they are represented are at present scanty.

Palæomastodon is represented by several species, the commonest being *Palæomastodon wintoni*, which must have been rather larger than a large cart horse. In this animal the skull approximates in many respects to that of the elephants proper. Thus the nostrils have shifted back till they are only a little in advance of the orbits, and the nasal bones are very short. At the same time the bones at the back of the skull are much more enlarged than in *Mæritherium*, owing to the increased development of spongy tissue within them. The upper incisors are now reduced to a single pair, the second, and form moderately large downwardly directed tusks, with a band of enamel on their outer side. The canines have disappeared. There are three upper premolars, the last having a pair of transverse ridges, while the molars have three transverse crests. The mandible is in many respects peculiar; the anterior spout-like portion is greatly prolonged, so that it projected considerably beyond the skull, and its extension is increased by the large procumbent incisors, corresponding to the second pair of *Mæritherium*. The other incisors, the canine, and the first two premolars have disappeared, and there is a long edentulous interval between the tusks and the third premolars. The fourth premolar is two-ridged, the first and second molars three-ridged, while in the third molar there may be as many as four transverse crests. The neck was a little longer than in the elephants, and the animal could doubtless reach the ground with its lower incisors, which (with the portion of the mandible projecting beyond the skull) were covered by the fleshy upper lip and nose, the terminal portion of which may have been more or less free and prehensile. The limb-bones are essentially similar to those of *Elephas*, particularly in the largest species, *Palæomastodon beadnelli*. The animal must have much resembled in its general appearance a gigantic pig, with a short neck and elongated snout.

Mæritherium and *Palæomastodon* are the only genera of Proboscideans known from the Eocene beds, and at present no member of the group has been found on any Oligocene strata; but when the lower Miocene beds are reached, Proboscidean remains are abundant, and we find them not only in African but also in European and probably Asiatic and American localities, the group having become widely spread since the Upper Eocene. In the Lower Miocene deposits of Europe two genera, *Tetrabelodon* and *Dinotherium*, are found, of which only the first is at present known in Egypt, where remains have been found at Mogara and in the Wadi Faregh. In

this animal, which is as large as an elephant, the skull is practically the same as that of the later Proboscidea; the tusks are now very large, though they are still directed somewhat downward, and have a band of enamel on their outer side. The milk molars, as in the earlier forms, are still replaced by premolars; but these are soon pushed forward and shed through the great increase in size of the permanent molars. Of these the first and second, though large, still have crowns with only three transverse ridges; the third molar, on the other hand, is still more enlarged, and its crown may be made up of five or six transverse crests; it is, in fact, so large that when it is fully cut not only the premolars but also the first molars are displaced, there being no room for them in the jaw. The anterior part of the mandible, with the procumbent incisors, has now attained an extraordinary length, projecting still farther beyond the skull than in *Palæomastodon*; in fact, in this genus we have the culmination of the specialization in this direction, and the long, straight snout must have presented a remarkable appearance, the animal having resembled an elephant in which the lower jaw was so elongated that it could reach the ground, and was covered with the fleshy snout, the end of which alone was free. So far as the Egyptian deposits are concerned, this is the last of the Proboscideans found; but it may be permitted to give a short summary of the subsequent changes which ended in the evolution of the modern genus *Elephas*. During the Miocene the long mandibular symphysis—probably because it had attained an unwieldly length—became rapidly shortened up, leaving the upper lip and snout free, as the movable proboscis so characteristic of the group. *Tetrabelodon longirostris*, of the late Miocene, represents a stage in this process. In this animal the symphysis is comparatively short, and although the two lower tusks attain a considerable size, they certainly could not reach the ground. At the same time the number of ridges in the molar teeth is increased to four in the two anterior ones. In the Pliocene the mandibular symphysis becomes still more shortened up, but in some species of *Mastodon* the lower incisors still persist, though of small size and usually soon shed. The number of transverse ridges in the molars increase and become deeper, till in *Stegodon* (from the Pliocene of the Siwalik Hills) the anterior molars may have six or seven ridges, the last one eight or nine. The valleys in these teeth are deepened, and may be more or less filled with cement. At the same time, in most cases, the milk molars are displaced by the development of the molars behind them, before they can be replaced from below by the premolars. In *Elephas* proper the elongated mandibular symphysis of the early forms is represented by a small process forming the chin of the mandible and never bearing any trace of lower incisors. The molars acquire a much greater number of transverse ridges and become

higher in the crown. In *Elephas primigenius* there may be as many as twenty-seven ridges in the last molar. All this long series of changes is illustrated by specimens shown in the paleontological galleries of the Natural History Museum, London, and representing, perhaps, the most complete history of any mammalian group yet known.

In the Upper Eocene beds the Hyracoidea are represented by two genera, *Megalohyrax* and *Saghatherium*, including several species. None of these throw any light on the relationships of the order; but some of them are of large size and indicate that formerly the group was of far greater importance than it is to-day, when its only representatives are a few comparatively small species, all of which, according to some authorities, should be placed in a single genus, *Procavia* (*Hyrax*).

The occurrence of remains of Sirenians in the Middle Eocene beds of Egypt has long been known, Owen having described—under the name *Eotherium*—a brain cast of one of these animals from the Mokattam Hills, near Cairo, so long ago as 1875, and further remains from the same locality were noticed by Filhol in 1878. Within the last four or five years not only have skulls and other portions of *Eotherium* been found, but remains of other genera have come to light, both from the Mokattam Hills and from the somewhat later deposits of the Fayûm. These early forms have been described by Dr. O. Abel and the present writer. Their chief points of interest are those in which they show approximation to the land mammals from which the group arose. Thus in *Eotherium* the pelvis has a complete obturator foramen inclosed by the pubis and ischium, and, judging from the acetabulum, there must have been a fairly well-developed hind limb. In the later forms, even at the top of the Middle Eocene, the pelvis has undergone considerable further reduction, the pubis and ischium not inclosing a foramen and the acetabulum being so small and indefinite that the hind limb must have been rudimentary. In these early Sirenians also the dentition approaches the primitive Eutherian type, there being three incisors, a canine, four premolars, and three molars on each side of the upper jaw. In the later types there is at most one pair of incisors, often much enlarged, while the canines and some of the premolars also are lost. This more normal structure of the pelvis and the character of the teeth show that a Sirenian such as *Eotherium* is not very remote from the terrestrial ancestor from which the group must have sprung; and it is very interesting to note that in the form of the pelvis and of the teeth this ancestral form must have much resembled *Mœritherium*, a fact strongly supporting Blainville's suggestion that the Sirenia and Proboscidea are closely related. Many other points of similarity might be pointed out, such as the form of the brain in *Mœritherium* and in *Eosiren* or *Eotherium*, and modern representa-

tives of the two groups also agree in a number of points. Thus in both there are (1) pectoral mammæ, (2) abdominal testes, (3) bilophodont molars, with a tendency to the formation of additional lobes behind, (4) the same arrangement of the intestines, and (5) to some extent the same character in the placenta. Altogether there seems to be very good reasons for regarding the Proboscidea and the Sirenia as offshoots of a common stock, the one being adapted for a terrestrial the other for an aquatic mode of life.

All the carnivora collected belong to the primitive group, the Creodonta, and all the species can be referred to genera already known from Europe or North America. A few of the limb bones found seem to indicate that some of these animals had adopted a semiaquatic mode of life, and it is possible that the seals originated from some such type.

Far more interesting than the Creodonts themselves is a group that is now definitely known to have originated from them, namely, the Zeuglodonts, usually—and probably rightly—regarded as primitive toothed-whales. Remains of the later members of this group are found widely spread over the world in the Eocene beds, occurring in North America, New Zealand, and Europe. It is only quite lately that any light has been thrown on the origin of these animals. Prof. E. Fraas described, from the lower Middle Eocene limestones of the Mokattam Hills, a skull which in all essential respects is that of a Zeuglodon, but at the same time the dentition is that of a Creodont carnivore, none of the peculiar characters of the Zeuglodont teeth being present. This specimen, to which the name *Protocetus* was given, proves fairly conclusively that the Zeuglodonts originated from some Creodont ancestor which acquired aquatic habits, and probably this happened on the northern coasts of the Ethiopian continent. From beds of a little later age in the Fayûm an animal almost precisely intermediate between *Protocetus* and *Zeuglodon*, has been described under the name *Prozeuglodon*. In this creature the skull approximates still more closely to that of the true Zeuglodonts, and the teeth have also acquired the serration characteristic of the group, though at the same time some of the premolars and molars have a third inner root, which is lost in the later forms. In the upper beds of the Middle Eocene of the Fayûm typical Zeuglodonts, e. g., *Zeuglodont osiris*, occur; so that in this region we have a complete passage from *Protocetus*, in which the teeth are those of a Creodont, to *Zeuglodon osiris*, in which they are typically Zeuglodont—that is, the molars are two-rooted and have serrated cutting edges. At the same time the narial opening shifts back, and although it is still well in front of the orbits and the nasal bones are long, the change is in the direction of the type of skull found in the early Odontoceti; and, although the relationship of these animals to the

Zeuglodonts has frequently been doubted, there seems much to be said in its favor. This question has lately been discussed by Fraas and by Abel.

Remains of birds are very rare, and with the exception of fragments of the skeleton of a heron-like wader, the only specimen of importance is the distal end of a tibio-tarsus, which is interesting, because it shows that probably a true Ratite (*Eremopezus*) existed in the Eocene in this region, and may be the ancestral type from which the Struthiones and Æpyornithes sprung—numerous common characters between the two groups having been pointed out by Burckhardt. A relationship with the South American Rheas is also possible. On the other hand, this bird may be merely another instance of the results of retrogressive change, leading to loss of flight and increase of size in some group of Carinate birds, such as has happened in the case of the Stereornithes and Gastornithes.

Among the Reptilia no very important new forms have been discovered. In the Middle Eocene remains of large and probably marine snakes are found, one of these (*Gigantophis*) having probably attained a length of 30 to 40 feet. Another (*Pterosphenus*) is of interest, because a closely allied species is found in North America also associated with Zeuglodonts. From the same horizon there have been collected remains of numerous Pleurodiran tortoises, a group formerly widely spread, but at the present day found only in the southern hemisphere. The most remarkable of the Egyptian Pleurodires is *Stereogenys*, in which the palate and mandible are modified to form broad, crushing surfaces, probably for breaking the shells of the animals which formed its food. In the Upper Eocene beds Pleurodiran tortoises are likewise found, the modern genus *Podocnemis* being represented by several species; but at this horizon the most notable chelonian is a gigantic land-tortoise (*Testudo ammon*), shells of which are comparatively numerous. This species approximates most nearly to the Aldabara and Madagascar giant tortoises among living forms. Numerous Crocodiles are found both in the Middle and Upper Eocene, and include both long and short snouted forms. One (*Tomistoma gavialoides*) seems, to some extent, to bridge the gap between the true *Tomistoma* and the Gharial.

Remains of fishes are found in several horizons, but none are of special interest. From the Middle Eocene are several peculiar sawfishes, and also several large Siluroids, which are curiously like species now existing in the Nile.

From the above account it will be gathered that a considerable number of Tertiary vertebrates are already known from Egypt, and include forms of great interest. At the same time, these must constitute a mere fraction of the faunas that have inhabited this region,

and therefore since the conditions seem to be very favorable to the preservation of vertebrate remains, it is to be hoped and expected that many new types of vertebrate life will be discovered, especially when the desert between the Fayûm and the Wadi Natrun can be thoroughly explored—a matter of no very great expense or difficulty.

The question of the relations of the Ethiopian land mass to other regions during the Tertiary period is one of great interest. That it is almost certain that Africa and South America were united during the Secondary period has been pointed out by many writers, and there is considerable probability that this union may have persisted till early Tertiary times, though there is great difference of opinion as to the position of the connection. It has even been suggested that a belt of shallow water and a chain of islands may have existed between Africa and Brazil so late as the Miocene. This connection between Africa and South America would account for a number of curious facts of distribution, as, for instance, the presence of the Hystricomorphine rodents and the Pelomedusid chelonians on both continents. The occurrence in the Santa Cruz beds of Patagonia of *Necrolestes*, a close ally of the Cape Golden Moles (*Chrysochloridæ*), has also been pointed to as evidence of this former union, but this has been considerably discounted by the discovery in the Miocene of North America of *Xenotherium*,[a] an animal which is almost certainly closely allied to the Chrysochloridæ, though it was described by its discoverer as probably a Monotreme.

Some South American palæontologists have asserted that certain groups of Ungulates found in the Tertiary beds of Patagonia are closely allied to, if not the actual ancestors of, some of the African subdivisions of that order, e. g., the Hyracoidea. There seems, however, to be no real ground for this belief, and it is far more probable that the two continents were separated before the main divisions of the Ungulata had become differentiated, and that such resemblances as do exist are merely the result of parallelism in the course of evolution of the group in the two areas.

The late Oligocene or early Miocene union between Africa and the Palæarctic continent has already been referred to in connection with the migration of the Proboscidea; but it is certain that other unions, probably of a temporary nature, must have occurred in earlier Tertiary periods. The presence in both the European and African Eocene of the same genera of Creodonts (*Hyænodon*, *Pterodon*, etc.) and of an Anthracotheroid approximating to *Brachyodus*, is evidence of this earlier junction.

The relations of Africa with Madagascar are also interesting.

---

[a] Douglass, "The tertiary of Montana," *Mem. Carnegie Museum*, vol. ii (1905), p. 204. The writer's attention has been drawn to the fact that Dr. W. D. Matthew suggested this relationship some time ago.

The mammalian fauna of Madagascar is a comparatively poor one, and is completely wanting in many of the typically African groups of mammals. Tullberg has accounted for this by supposing that the eastern part of Africa, with Madagascar, was separated from the main southern and western African continent by a belt of sea, and that it was only after the isolation of Madagascar that these two parts of the Ethiopian continent united, and the richer fauna of the southern and western portions spread over the whole. This probably occurred in the Oligocene, at which time the union with southwestern Asia and Europe took place, followed by the dispersal into the northern continent of the Proboscidea and other groups.

The importance of Africa in the history of the Mammalia is further increased by the fact that, as Stromer has pointed out, some part of the region has probably been above the sea since Permo-Triassic times, during which a great variety of land reptiles existed, some of which, the Theriodonts, approximate very closely to the mammalian type, and, in fact, are probably the stock from which the Mammalia sprung. This being so, it is by no means improbable that somewhere in this continent beds of Jurassic and Cretaceous age will be found, containing remains of animals which will completely bridge the gap between the two great and now widely distinct groups—the Mammalia and Reptilia.

POLYEMBRYONY AND THE DETERMINATION OF SEX.[a]

Résumé of the observations of P. Marchal.[b]

By E. Bugnion.

Polyembryony is the spontaneous division of the germ into a number of distinct individuals.[c]

Hardly more than a glimpse into a new epoch, this phenomenon, of the highest scientific interest, was observed during the past summer by Paul Marchal, professor at the Agronomic Institute of Paris, in parasitic Hymenoptera of the genera *Encyrtus* and *Polygnotus* and recognized by this same author as being the normal mode of reproduction of these insects.

Let us first consider *Encyrtus fuscicollis* Dalman. Scarcely a millimeter in length, this minute Chalcid develops as an endoparasite at the expense of a number of species of moths or Hyponomeutas (*H. cognatella* or *evonymi* of the spindle tree, *mahalebdella* or *padi* of the mahaleb or plum of Santa Lucia, *padella* of the hawthorn and sloe tree, *malinella* of the apple.)

If one examines under the microscope the caterpillars of *Hyponomeuta* (for example, *H. cognatella*) at the end of April or during the first half of May, one finds nearly always, or at least among some of them, those with embryos (and later with larvæ) of *Encyrtus* associated in the form of chains or rows.

These chains, which I have already described in the Recueil zoologique Suisse, v. V, 1891, are composed of 50 to 100, or even 120, individuals. The sac which contains the parasites presents itself as a whitish tube, sometimes bi- or tri-furcate, flexible, folded upon itself, floating in the lymph of the caterpillar outside of the intestine. Formed of an envoloping membrane (cuticle), it is clothed interiorly

---

[a] See the works cited: Marchal, 1897, 1898, 1899, 1903, 1904, and 1904*a* (principal memoir).

[b] Translated, by permission, from Bulletin de la Société Vaudoise des Sciences Naturelles, 5 ser., Vol. XLII, No. 155, March, 1906.

[c] Brandes (1898) proposed, in place of polyembryony, the term *germinogony*. One could also say *spontaneous blastotomy*.

with a layer of epitheloid cells and incloses an albumino-fatty mass in which the embryos are immersed.

Later, after the larvæ have attained a certain size (at the end of May or beginning of June), the row, which may have a length of 3.5 cm., presents a series of wrinkles and constrictions; each fold contains a larva inclosed in the nutritive substance. At the end of June, after the parasites have completed their first molt, they burst the epithelial tube which enveloped them and are found at liberty within the body of the caterpillar. This period (second larval phase) lasts about eight days. At last, the larvæ having consumed the interior of the larva, each one of them prepares for the pupal period by inclosing itself in an ovoid cocoon, formed, according to Marchal, by the external cuticle puffed out and detached from the body. The caterpillar, the skin of which molds itself exactly over the cocoons, thereafter was little more than a rigid sheath, embossed, and appearing partitioned within. The transformation of the larva into a nymph by means of a new molt takes place a little after the partitioning of the caterpillar, and from the time of this event until the eclosion of the Encyrtus one counts twenty days.

The Hyponomeutas do not have more than one generation annually. The eclosion of the moth (*H. cognatella*) takes place in July, copulation in the following days; the eggs are deposited a short time afterwards in little clusters of 40 to 70, which the insect attaches to the branches of the spindle tree.

The young caterpillars, hatched in September or October, rest during six months, crouching under the scaly covering which protects the egg mass until the first days of April, before leaving their shelter.[a]

The facts brought to light by Marchal may be summed up as follows:

1. Encyrtus is, the same as its host, Hyponomeuta, of only one generation annually.

2. The oviposition of Encyrtus takes place shortly after that of Hyponomeuta, in July or in August, following the species parasitized, and it is into the egg of the moth that the parasite introduces its own egg.

3. Each chain of embryos proceeds from a single egg, as a result

[a] It is ordinarily between the 5th and the 18th of April, exactly at the time when the young leaves of the spindle tree expand, that the minute caterpillars of *H. cognatella* leave their retreat and reach the nearest buds. Afterwards hiding in the interior and drawing toward them the leaves by means of a few threads, they form a little nest, which gives them at the same time food and shelter. Their length at this period is from 0.7 to 0.8 millimeter. After this they grow rapidly, but it is only at the end of a few weeks, after their size has reached about a centimeter, that their webs, having become more voluminous, begin to attract attention. (*Bugnion*, 1893, p. 319.)

of the division of the germ into numerous distinct individuals during the morula stage.

4. One egg of Hyponomeuta ordinarily does not receive more than one egg of Encyrtus. However, when it happens that one egg of Hyponomeuta is stung two or three times (perhaps by different individuals) a corresponding number of chains of embryos are formed within the caterpillar.

5. The albumino-fatty (nutritive) mass in which the embryos are immersed results from the proliferation of the amniotic cells furnished by the germ of the Encyrtus (derived from the paranucleus).

6. The enveloping membrane, as well as the epitheloid cells which clothe its interior, is formed at the expense of mesenchymatous elements furnished by the organism of the host (Hyponomeuta). These formations can be compared to an adventitious cyst destined to isolate the parasites.

It is on the eggs of *Hyponomeuta malinella* that the act of oviposition of Encyrtus was observed for the first time (1897).

Marchal, having inclosed an apple branch in a cage of gauze, placed within the cage some of the cocoons of the moth. The moths issued on the last days of June and the first days of July. On the 4th of July a goodly number of copulations were achieved; on the 6th one could already observe many freshly deposited egg masses on the twigs. On the 18th a large number of Encyrtus having emerged from the parasitized caterpillars deposited in the cage, Marchal noticed that at 1.50 in the afternoon (at the moment when the sun sends forth its hottest rays) an Encyrtus, which, perched on an egg mass of Hyponomeuta, appeared to be in the act of oviposition. Taking advantage of so favorable an occasion, he could, during four consecutive hours, follow with the lens the minute parasite, which completely absorbed in its work, passed from one egg mass to another, piercing the eggs with its sting. The operation lasted each time a little more than half a minute (two minutes toward the end of the journey).

Other observations were carried on with the parasites of *H. mahalebella*. As this moth emerges later than the others, Marchal could, thanks to this circumstance, obtain new ovipositions of *E. fuscicollis* during the period comprised between the 12th and the 22d of August, and complete at the same time the necessary material for his work. The author concludes from his last observations that Encyrtus does not live more than ten days in the imago state.

The investigation of the egg of Encyrtus within the egg of the moth is extremely difficult, if one limits one's self to dissociating the vitellus. Marchal employs most especially the method of section cutting. Having collected, on September 10, 1901, some parasitized

egg masses of *H. mahalebdella*, and having fixed them in Gilson liquid, stained them with carmine, and cut them into fine sections, he succeeded in discovering the egg of Encyrtus included within the general cavity of an already large and advanced embryo of Hyponomeuta. The egg is so minute in size that, at the most, one can not make a series of more than four to five sections including its substance. Its contour is ovoid, clearly defined, and one can not see the least trace of the eggshell and the pedicle observed before oviposition. There are in its interior five nuclei immersed in the as yet undivided protoplasmic mass, of which four are smaller, rounded, alike among themselves, and one more voluminous placed eccentrically, of irregularly lobed form, presenting a very fine and very dense reticulation. We will state further that the four small nuclei (embryonal nuclei) are destined to produce by successive proliferation the entire chain of embryos, while the larger nucleus (paranucleus or amniotic n.) constitutes the first formation of the amnios.

At this stage the egg of Encyrtus is not inclosed in any membrane; one only perceives in its vicinity the presence of some mesenchymatous cells, which belong to the host. It is a little later, when the number of embryonal nuclei has increased to 8 or 10, that an adventitious cyst begins to form by the drawing near of the mesenchymatous elements, which press against the egg, and thus form a lining of flattened cells. As to the amniotic cells derived from the paranucleus, their rôle is to form the albumino fatty body which contains the embryos and which is soon to serve for the alimentation of the young larvæ.

At the end of September the little caterpillars hatch, but they confine themselves to gnawing the remains of the eggs and rest until spring beneath the carapace which covers them. In examining these caterpillars under the microscope, one can perceive among certain of them the presence of one and sometimes two or three small rounded bodies, still difficult to distinguish, floating among the viscera. These little bodies, which are the eggs of Encyrtus inclosed in their cyst, may be studied at the time both by picking to pieces in water with osmic acid and by the method of sectioning. Examined by transparency at the end of autumn, the egg offers a mass of ovoid or globular protoplasm in which are immersed, first, a mass of embryonal nuclei pressed one against the other, to the number of 15 or 20; second, a large paranucleus placed eccentrically, sometimes divided into two segments.

The stage which has been described persists nearly without modification throughout the winter. However, in a goodly number of eggs one can perceive from the middle of March and even of February a

grouping of the embryonal nuclei, which already indicates the division of the germ into many embryos. The formative vitellus (characterized by its clear tint) is divided into many rounded masses, isolated one from the other, each inclosing a group of nuclei. These last, which before had two nucleoles, now present multiple nucleoles, which are arranged in two rows, indicative of an approaching proliferation. Some of these are already on the way to kinesis.

But it is during the period when the young larvæ leave their winter shelter and begin to gnaw the leaves that the phenomena of polyembryony reach their greatest intensity.

The egg, at first spherical, grows with an extraordinary rapidity, and little by little assumes an elongate ellipsoid form. It is under this aspect and with a considerably increased diameter that one finds them in the interior of the caterpillars of the spindle tree about the 20th of April. The same stage appears in the caterpillars of the mahaleb about the 10th of May.

Examined at this period in thin sections, the germ of the Encyrtus is found composed of these small rounded masses, which had, in certain cases, commenced to take form at the end of the winter.

Grown much more numerous, these are formed of small masses of protoplasm, containing the nuclei (to the number of 8 to 10 in each mass), and already show the cellular limits distinctly enough. Each one of these masses is located in a rounded cavity, with clear-cut outline, hollowed out in the common granular (nutritive) protoplasm, as with a punch. In order to see the cavity well it is necessary in every case to fix the object with Fleming solution and not with corrosive sublimate. It may be colored afterwards with safranine. These bodies, which may be compared to small buds and which we shall hereafter call *muriformes*, increase by multiplication of their elements; but, arrived at a certain size—each of them made up at the time of 12 to 15 cells—they themselves divide by breaking up.

During the last days of April, when the polygerminal complex of Encyrtus has attained a half millimeter in length and has taken the form of a sausage, the muriform bodies are present in the interior to about the number of 40, well differentiated from each other and immersed in the common granular mass; the number of cells which compose them is always much reduced, ranging from 8 to 12.

About the middle of May, at the time when the polygerminal complex has grown into a chain 3 to 4 mm. long, the buds have multiplied to more than a hundred and now constitute the true morules. These have from 20 to 40 cells each, which through mutual pressure on all sides present a polygonal form. From this time on the embryonic laminæ begin to unfold and the body begins to take form. The embryo, abandoning the spherical form, tends toward

the discoidal form through compression of its surfaces from opposite sides; it afterwards takes a reniform shape, as the result of the appearance of a deep hilum, which grows from above downward and corresponds to the dorsal region, while the convex surface opposite to the hilum corresponds to the ventral face. This very characteristic form generally shows itself by the 25th of May (H. of the spindle tree). Finally, about the 10th of June, the embryos have reached the larval state, and the chains of Encyrtus have reached their full length and present the characteristic form described at the beginning of this article.

The most striking fact in the development of Encyrtus is, then, that a single egg deposited within the egg of the moth proliferates by division of the nucleus in such a manner as to form a certain number of plurinuclear masses, and that these, dividing in their turn, produce as many morules as there will be embryos in each of the chains.

Polyembryony being, as appears from what precedes, the ordinary mode of development of *E. fuscicollis*, it may be foreseen that the study of the Chalcidids, particularly of the group of Encyrtids, will result in the discovery of other analogous cases.

Marchal already cites *Encyrtus testaceipes* Ratz., a parasite of *Lithocolletis cramerella*, leaf-miner of the oak. He could not see, it is true, more than the advanced stages of the development of this species, the observation having been made in October. The larvæ, to the number of 12 to 15 in a caterpillar, had for the greater part already formed their cocoon; but in some caterpillars the parasites were grouped in an epithelial tube similar to that of *E. fuscicollis*. The structure of the tube being absolutely the same, there is no doubt that development takes place in the same manner.

According to Giard (1898, Bull., p. 127–129) *Litomastix truncatellus* Dalm. (*Copidosoma* Mayr), may present an embryonal multiplication of the most active kind. Close to 3,000 of these insects can succeed in developing from a single caterpillar of *Plusia gamma* L., whilst the number of eggs contained within the ovaries of the female does not exceed a hundred.[a]

Another case of polyembryony was observed by Marchal in *Polygnotus minutus* Lindeman (*Platygaster*), a minute parasitic Proctotrypid (length ½ mm.) of the Cecidomyids of wheat and oats (*C. destructor* Say and *avenæ* Marchal). The embryos, which one finds to the number of 10 to 12 in the gastric sac of the Cecidomyia larva,

[a] Howard (1892, p. 582), who counted 2,500 specimens of *Litomastix truncatellus* which had issued from one caterpillar of *Plusia brassicæ* Riley, calculated the number of eggs contained in the ovaries of the female in the vicinity of 160 (the maximum 300).

are grouped in such a manner that they form a single ovoid mass, rocked by the contractions of the stomach walls.[a]

The author, it is true, has not as yet observed Polygnotus in the act of oviposition, but having found the freshly deposited eggs in the gastric cavity he succeeded in following the multiplication of the nuclei, afterwards the grouping of the cells into a number of individuals just as distinctly as in Encyrtus. Polyembryony is therefore well established for this species. The only differences from *E. fuscicollis* are: First, that the morula stage follows a genuine blastula with central cavity, preceding the formation of the embryo; second, the proliferation of the germ being considerably less active, the number of individuals proceeding from one egg appears not to exceed a dozen in number. (Marchal, 1903 and 1904*a*.)

Other examples borrowed from the whole animal kingdom may be associated with the polyembryony of insects.

In the Cyclostomids (Bryozoa) one encounters a budding which takes place in the egg at the beginning of development. In the genus *Lichenopora* this budding is replaced by the breaking up of the first embryo into a great number of secondary embryos. Thus we have here a phenomenon comparable to that which we have found in the Hymenopterous parasites. It should nevertheless be noted that the secondary embryos thus formed already present an indication of the embryonal lamellæ (planula), whilst the morules of Encyrtus or the blastules of Polygnotus do not present any apparent differentiation. In the other Bryozoa (*Lophopus*, *Cristatella*) one likewise observes a budding in the egg, but it occurs at a much later period: it is only when the embryo, having already clearly differentiated two ectodermic and mesodermic lamellæ, is going to transform into a free larva that it buds forth many polypoids at its aboral pole.

In the worms, Kleinenberg in 1879 made known the curious case of *Lumbricus trapezoides*, in which the egg develops into two embryos; here the multiplication is caused by a sort of internal budding, interposed at the gastrula stage, before the differentiation of the lamella has yet taken place.

In the Tunicates the *Diplosomas* offer a curious case of precocious budding, which gives the illusion of the simultaneous formation of two embryos in the same egg; but in realty it is a case of the internal budding of an already differentiated embryo (Salensky, Caullery, Pizon, Perrier). In *Pyrosoma* the budding likewise takes place in

[a] In obedience with the contractions of the stomach walls the polygerminal mass of Polygnotus is carried by rythmic movements, which transport it by turns from in front backward and from behind forward. This movement, of which the effect can be compared to that of the shaking of eggs, would have, according to Marchal (1904), an influence toward the division of the germ.

the egg, but in a slower manner, and it is only when the embryo is formed that it emits a ventral stolon; it afterwards divides transversely into four buds, each one of which develops into a new individual (according to Huxley, Kovalevsky, Seelinger, etc.).

From the cases above cited, where the budding is effected in the egg, one passes on insensibly to the very frequent and well-known processes in which agamic reproduction takes place after the animal has already left the egg (Cœlenterata, Orthonectids, Dicyemids, Plathelmintha, Tunicata). The preceding observations appear, therefore, to establish a continuous series linking the polyembryony of the Hymenoptera with the cases of agamogenesis that occur in the advanced stages of development.

Again, from a very general point of view, the processes of polyembryony may be associated with the cases of experimental blastotomy recently recorded by several authors.

Driesch (1892), causing a temperature of 31° to act on the eggs of Echinids, obtained a separation of the blastomeres into two or more groups; Loeb (1893) obtained a like result by mixing equal parts of distilled water with the sea water in which the eggs are found.[a]

Another experiment carried out by Loeb (1894) with the eggs of sea urchins and by Bataillon (1900) with the eggs of Petromyzon and of Teleosteans consisted in dividing the egg into several groups of blastomeres by means of a hot needle. Both of them obtained complete larvæ, each blastomere or group of blastomeres again constituting an embryo by itself.

Ryder (1893) obtained double monsters by shaking the eggs of the trout. The vitellus accumulates on the two sides of the egg, forming two distinct individuals.

In the same way it is possible, by making a constriction around the egg of *Triton* with a silk thread, to produce two complete larvæ, united only by the skin of the abdomen. (Endres, 1895; Speman, 1900 and 1901.)

These investigations speak, as one sees, in favor of the so-called *isotropic* constitution of the egg, each blastomere or group of blastomeres isolated in the manner indicated being capable of forming a complete individual.

Marchal expresses the facts very well in saying that as much in spontaneous polyembryony as in experimental blastotomy each part of the egg contains the complete hereditary patrimony capable of

[a] The egg in absorbing the water bursts its membrane; a portion of the cytoplasm issues from the mouth of the rupture and forms a gross hernia, which the author calls *extraovat*. The nucleus divides and sends forth a young nucleus into the extraovat. In this manner, like the *intraovat*, it develops into a complete larva (after Delage, L'hérédité, 1895, p. 331).

accomplishing the formation of an individual conforming to the specific type.

Another question which arises is that of determining whether, in the class of insects, polyembryony may be considered as having preceded or followed phylogenetically the other modes of agamic reproduction, such as the pedogenesis of the Cecidomyidæ or the cyclic parthenogenesis of the Aphides and the Cynipidæ. Harmer, from the Bryozoa, arrived at the conclusion that embryonic division may be a consequence of the blastogenic faculty of the adults. Perrier looked in the same way upon all the budding animals.

Considered from this point of view, the polyembryony of the Chalcididæ appears, not as an initial phenomenon, but as a secondary adaptation due to an acceleration of embryonic processes (*Tachygenesis* of Perrier, 1902). The object of this adaptation is to accomplish the preservation of the species by pushing its multiplication to the highest limit possible, since the existence of the adult Encyrtus is short and precarious.

As to the determining cause of the division of the germ, it is, according to Marchal, in the sudden precipitation of more dilute liquids into the midst of the nourishing medium and in a concomitant modification of osmotic exchanges to the interior of the cells. It is to be noted that in Encyrtus polyembryony actually reaches its greatest intensity at the moment when the caterpillar of the Hyponomeuta begins to feed (first days of April) and in Polygnotus at the period when the young larva of the Cecidomyia gorges itself with sap. Now the production of sudden changes induced by osmotic pressure constitutes precisely one of the processes employed to bring about the separation of the blastomeres and their development into a number of distinct individuals, as has been demonstrated by the already mentioned experiments of Loeb and Bataillon.[a]

Furthermore, connected with polyembryony is the question of the determination of sex, and in this particular it offers a special interest.

I have already observed, in the course of my studies on Encyrtus (1891, p. 527), that all the individuals emerging from the same caterpillar appertained, in most cases, to one sex only.[b] A total of 21 carefully controlled observations gave me 5 times males exclusively, 9 times females exclusively, 3 times a great majority of males, 1 time a great majority of females, 3 times males and females in nearly equal numbers.

Marchal has likewise observed that the Polygnotus that issued from a single larva of Cecidomyia nearly always belong to the same sex (1904, p. 314).

---

[a] See on the subject of the influence of pressure, Bataillon, 1900*a*.

[b] The observations relating to the parthenogenetic reproduction of *Pteromalus puparum* are recorded in the mémoir of Howard.

These facts, which we had crudely tried to attribute to occasional parthenogenesis[a] (the caterpillars giving exclusively males being, according to this supposition, those which had been stung by unfertilized Encyrtus) we now explain in a far more rational manner.

In man, genuine twins, inclosed in a single chorion, probably proceed from one egg. In spite of the different hypotheses which have been proposed, particularly in recent years, on the subject of their formation (Rosner, 1901) it is natural to admit that the twins develop by the separation of the egg into two parts (spontaneous blastotomy). Now it has been determined that genuine twins are always of the same sex. It is also known that, apart from some extremely rare cases, there is identity of sex in double monstrosities. The exceptions to this rule are probably explained by the fact that certain monstrosities form by the union of two eggs.

Still another case presents itself in the mammals, and which, even more than the preceding ones, seems comparable to those of Encyrtus and Polygnotus. It is that of the armadillos (*Dasypus* or *Tatusia*). This, in fact, does not involve an accidental case, but a phenomenon of specific character; these animals bring into the world, according to the species, a litter of 4 to 11 young, which are all and always of the same sex. Now it was determined by Shering (1886)[b] that all the fetuses are enveloped in a common chorion and in consequence belong to the type of true twins. Rosner (1901) had been able to crudely explain the fact by the habitual presence of a number of ovules within a single graafian follicle and had likewise concluded that all the cases of monochorial budding pregnancy might be explained in the same manner. But Cuénot (1903), reopening the question, ascertained that in the species studied by Rosner (*T. novemcincta* L.) the monovular follicles are five times more numerous than the pluriovular ones. It is therefore impossible to admit that the latter alone furnish fecundable eggs, and the author concludes

---

[a] This observation is easy to repeat. One knows that the caterpillars of Hyponomenta group their cocoons in more or less voluminous clusters (nests) attached to the branches. The chrysalids are to be found within the cocoons, in June with the Hyponomenta of the spindle tree, in July with the Hyponomenta of *Prunus padus*. The parasitized cocoons are immediately recognized by their hard consistency; it is easy to pull them apart and isolate each of them in a vial (well dried), closed by a paper tied over the neck. After all have issued the Encyrtus may be killed by putting a few drops of chloroform on the paper. Then treating them with alcohol, oil of cloves, and Canada balsam, all the Encyrtus proceeding from the same vial are mounted on a single slide and one can then observe, under the microscope, the proportion of the two sexes.

[b] Shering examined two pregnant females of *Tatusia hybrida* Desm. of Paraguay; each one of them contained eight fetuses, all masculine in both cases, enveloped in a common chorion.

that, in all probability, the multiple twins of the armadillo proceed from a single egg.

The discovery of Marchal comes just at the right time to throw a new light on this question, so interesting and so much discussed.

From the fact that Encyrtus and Polygnotus which have issued from the same larva are nearly always all males, or all females, it is to be concluded that this is the one natural result of polyembryony and that the sexes will be separated in this manner whenever the embryos proceed from the division of a single egg.

The fundamental fact derived from this study is that all the caterpillars, or larvæ which contain a single chain of embryos, produce imagoes pertaining to a single sex. But as the same caterpillar frequently supports two or three chains of embryos, there is nothing astonishing in seeing males and females issue in more or less equal numbers. Finally, the cases in which one finds individuals of both sexes, but in unequal numbers, are explained by the partial abortion of one of the chains and the survival of only a few individuals, alongside of another normally developed chain.

It appears that the discovery of polyembryony confirms a fact already suspected but incompletely demonstrated up to the present—that is, the knowledge that the determination of sex within the fertilized ovum is definitely consummated before the first segmentation of its nucleus. If, therefore, the facts taken from the observation of the parasitic Hymenoptera apply equally to the higher animals, it is inexact to speak, as is sometimes done, of an indifferent embryonal period from the sexual point of view. The indifference is probably apparent rather than real, and it appears probable that once fecundation is effected the sex is irrevocably fixed.

Works cited.

1879. Kleinenberg, N.: The development of the earthworm. Lumbricus trapezoides Dugès. Quart. jour. micr. sc., vol. 29, p. 206.

1891. Bugnion, E.: Recherches sur le développement postembryonaire, l'anatomie et les mœurs de l'Encyrtus fuscicollis. Recueil zool. Suisse, T. V. pp. 435–536, pl. xx–xxv.

1892. Howard, L. O.: The biology of the Hymenopterous Insects of the family Chalcididæ. Proc. U. S. Nat. Museum, vol. 14, pp. 567–588.

1892. Driesch, H.: Entwickelungs-mechanische Studien. Exp. Veränderungen des Typus der Furchung (Wirkung von Wärmezufuhr u. von Druck). Zeits. f. wiss. Zool. vol. 53, pp. 160–183.

1893. Bugnion, E.: Note sur la résistance de la Teigne du fusain aux basses températures de l'hiver. Bull. Soc. entom. Suisse, t. 8.

1893. Driesch, H.: Exogastrula u. Anenteria (Ueber die Wirkung von Wärmezufuhr auf die Larvenentwickelung der Echiniden). Mitth. der Zool. Stat. zu Neapel, vol. 11, pp. 221–255.

1893. Driesch, H: Ueber Variationen der Mikromerenbildung (Wirkung von Verdünnung des Meerwassers). Ibid.

1893. Loeb, J.: The artificial production of double and multiple monstrosities in sea urchins. (Biol. Lectures Mar. Biol. Lab., Wood's Holl, Boston.)

1894. Loeb, J.: Ueber eine einfache Methode zwei oder mehr zusammengewachsene Embryonen aus einem Ei hervorzubringen. Pflüger's Archiv, vol. 55.

1895. Endres, H.: Ueber Anstich- u. Schnürversuche an Eiern von Triton taeniatus. Sitzber. der zool.-bot. Section der schles. Ges. f. vaterl. Cultur, 15 Nov.

1897. Marchal, P.: Les Cécidomyies des céréales et leurs parasites. Ann. Soc. ent. Fr., t. 56, pp. 1–105.

1898. Marchal, P.: La dissociation de l'œuf en un grand nombre d'individus distincts chez Encyrtus fuscicollis. C. R. Ac. sc. Paris, t. 126 pp. 662–664. C. R. Soc. biol. 10e s., t. 5, pp. 238–240. Bull. Soc. ent. Fr., pp. 109–111.

1898. Brandes, G.: Germinogonie, eine neue Art der ungeschlechtlichen Fortpflanzung, Zeitsch. für die ges. Naturwiss. Halle, t. 70, pp. 420–422.

1898. Giard, A.: Sur le développement de Litomastix truncatellus Dalman. Bull. Soc. ent. Fr., pp. 127–129.

1899. Marchal, P.: Comparaison entre les Hyménoptères parasites à développement polyemryonnaire et ceux à développement monoembryonnaire, C. R. soc. biol. 11e s., I, pp. 711–713.

1900. Bataillon, E.: Blastotomie spontanée et larves jumelles chez Petromyzon Planeri. C. R. Ac. sc. Paris, t. 120, p. 1201.

1900*a*. Bataillon, E.: Pression osmotique de l'œuf et polyembryonie expérimentale. C. R. Ac. sc. Paris, t. 130, pp. 1480–1482.

1900. Spemann, H.: Experimentelle Erzeugung zweiköpfiger Embryonen. Sitzungsber. d. phys-med. Ges. Würzburg.

1901. Spemann, H.: Entwickelungsphysiologische Studien am Triton-Ei. Archiv. für Entwickelungsmechanik, vol. 12.

1901. Rosner, ——.: Sur la genèse de la grossesse gémellaire monochoriale. Bull. Acad. sc. de Cracovie. No. 8, nov.

1902. Perrier, E., et Gravier, Ch.: La tachygenèse ou accélération embryogénique. Ann. sc. nat. zool. 8e s., t. 16, pp. 133–371.

1903. Cuénot, L.: L'ovaire du Taton et l'origine des jumeaux. C. R. Soc. biol., t. 60, pp. 1391–1392.

1903. Marchal, P.: Le cycle évolutif du Polygnotus minutus Lindem. Bull. Soc. entom. Fr., pp. 90–93.

1904. Marchal, P.: Le déterminisme de la polyembryonie. C. R. Soc. biol., p. 468 (note préliminaire).

1904*a*. Marchal, P.: Recherches sur la biologie et le développement des Hyménoptères parasites. La polyembryonie spécifique ou germinogonie. Arch. zool. exp. (4), vol. 2, pp. 257–335, pl. IX–XIII.

ELEPHAS PRIMIGENIUS.
Restoration by E. Pfizenmayer.

A CONTRIBUTION TO THE MORPHOLOGY OF THE MAMMOTH, ELEPHAS PRIMIGENIUS BLUMENBACH; WITH AN EXPLANATION OF MY ATTEMPT AT A RESTORATION.[a]

By E. Pfizenmayer.

Our knowledge of the fossil pachyderms has received important accessions in every respect through the mammoth carcass brought to light in the Siberian "taiga," on the Beresovka River, and discovered by Lamuts, which was recovered in a more nearly perfect condition than any hitherto obtained. The find on the Beresovka has not only made our knowledge of the skeleton of *Elephas primigenius* complete for the first time, but the left tusk, which was preserved, has solved in a satisfactory manner the question as to the position of this modified incisor tooth in the skull, and especially as to its curvature and the direction of the tip, since it was possible to determine positively its original position in the alveolus. Our morphological knowledge of the mammoth also received important additions through the Beresovka discovery, in spite of the fact that the state of preservation of the soft parts was less satisfactory than that of the skeleton.

In the light of our present knowledge of the mammoth, and especially of its exterior, the various existing attempts at a restoration need important corrections. Apart from the many fanciful sketches intended to portray the exterior of the animal, all the more carefully made restorations show the faults of the skeleton, hitherto regarded as typical, on which they are based, especially the powerful semicircular and upward-curved tusks, the long tail, etc.

As these false conceptions of the exterior of the mammoth, both written and in the form of pictures, are contained in all zoological and paleontological text-books, and even in scientific monographs, it

[a] Translation, by permission, of Beitrag zur Morphologie von *Elephas primigenius*, Blumenb. und Erklärung meines Reconstructionsversuches (Separat-Abdruck aus den "Verhandlungen der Russisch-Kaiserlichen Mineralogischen Gesellschaft" zu St. Petersburg, Bd. XLIII, Lief. 2, 1906).

For a further account of the Beresovka Mammoth, see the Smithsonian Report for 1903, pp. 611–625, pls. I–II.

seems necessary to construct a more nearly correct picture, based on our present knowledge. I have ventured on this task, because as a member of the latest expedition for mammoth remains I was permitted not only to become acquainted with this newest find while still in its place of deposit and to take part in exhuming it, but also to visit the zoological museum of St. Petersburg, which is so rich in mammoth remains, for the purpose of studying the animal more in detail.[a]

The trunk is lacking entirely in the Beresovka Mammoth, and the soft parts of the head (except the tongue) were destroyed in this new specimen. The trunk, however, probably differed scarcely at all in form from that of the recent elephants. The numerous figures found in the caves of southern France, a part of which the dwellers in these caves drew on the walls, and a part engraved on pieces of bone, indicate to us that the men of the stone age knew the mammoth very well, and even hunted it.

These drawings all show a strongly-developed trunk and give us, besides, many other noteworthy clues regarding the exterior of the mammoth. Very interesting is a published "mammoth" drawing of this kind which was found in the year 1894 in the cave "La Mouthe," in Dordogne, and of which I was made acquainted shortly before the printing of my work.[b] In this drawing, which is executed in a quite childish fashion, with only a few strokes, the old artist has, above all, represented the characteristic position of the tusks in a very striking manner: the short tail is also indicated by one stroke, and a powerful trunk is likewise to be seen in the drawing. As this sketch, made centuries ago by a human contemporary of the mammoth, sustains in a gratifying manner my view of the position of the tusks in the full-grown animal (to be explained below), I have copied it in fig. 1.

The old mammoth skeleton of the zoological museum (of St. Petersburg), exhumed in 1806 in the Lena delta, still shows to-day the partly-preserved and blackened soft parts of the head. A Yakutsk merchant, Boltunoff, saw this mammoth many years before the arrival of Adams in an alleged better state of preservation, and speaks, in his description (still extant) of the carcass, of a long trunk which he noticed on the head.

Boltunoff also saw both ears on the Adams mammoth head, and gives their length as 6 *Werschok* (26.5 cm.). One, the right ear, is still preserved, and as it is complete it shows us that in the mam-

---

[a] I will not neglect to mention that in the development of my restoration in water color, as well as in the preparation of the text figures, I received much assistance through the artistic skill of my wife.

[b] I owe this "mammoth" sketch to the kindness of the archeologist, Count P. A. Putjatin. It is published in Émile Rivière's "The engraved and painted walls of the cave of La Mouthe (Dordogne)," pl. 2, fig. B. Paris, 1905.

moth the ear was much smaller than it is in the Indian elephant. The length of the ear as given by Boltunoff is too short. It is really 38 cm. long, and its greatest breadth (in the middle) is 17 cm. From the stumps of the broken bristles and soft hairs on this ear, which in some places on the outerside, and especially on the borders, are still quite thick, it appears that the ears, like the whole body, bore a thick covering of short, woolly hairs and longer bristle-like hairs.

The huge head passes into a short neck, which appears shorter than it really is on account of the powerful development of the muscles; and this joins a thick body, which is short in proportion to its height.

The tail, first made known through the Beresovka find, was 35 cm. long in this mammoth (measured along the underside), and

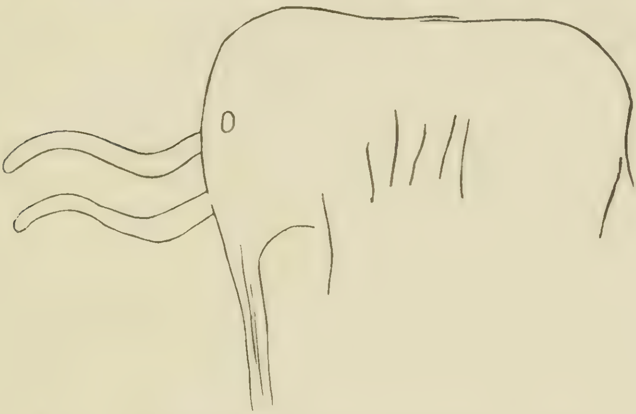


FIG. 1.—Drawing of mammoth in the cave of La Mouthe, Dordogne.

hence decidedly shorter than in existing elephants. The number of vertebræ was only twenty-one.

The legs are thickly covered with hair throughout, from the horny tips of the toes upward. The skeleton of the foot shows important deviations from that of the existing elephants. Metacarpal I and metatarsal I bear no phalanges; the remaining four metacarpals and metatarsals bear only two; the ossification of the third (or terminal) phalanx takes place only in entirely full-grown examples, while in younger individuals, such as the Beresovka Mammoth, it is rudimentary and cartilaginous.

If, therefore, the mammoth in the conformation of its body does not differ materially from its living allies, except in the characters already mentioned (although it exceeded them both in size), yet by reason of its characteristic tusks and its hairiness, it had a quite different appearance.

Regarding the hairy coat of the mammoth, in so far as it is revealed to us through the Siberian carcasses which have remains of the

original hairy covering, views are at present diverse. Through the discovery of Siberian mammoths with partially preserved soft parts, the question of the hairy coat is only in part definitely settled.

All the different assertions regarding the mane of the animal are due to suppositions, or rest entirely on untenable conjectures. For in every case only a small part of the skin of the body was found more or less nearly intact, and in these pieces the woolly hair remained only partially fixed, while the long bristles, if present, were at best more or less broken and usually quite loose, so that they could only be collected from around the carcass.

In the Beresovka Mammoth the circumstances were the same as regards the hairy covering of the body. As in this animal, the epidermis was decomposed, so that the hairs had rotted at the roots, the short, woolly hair remained fixed only on the parts which were covered with earth and protected from the weather, as, for example, on the left fore leg and the right hind leg, some places on the belly, etc. The long bristles were only sparsely present among the remains of the woolly coat, and were everywhere more or less broken. For the space of a meter about the carcass the loess was in places unmistakably set with hairs, which were often assembled in larger or smaller bundles. As already remarked above, it was principally on the legs, where they had been covered with earth, that the thickly-felted woolly hair remained, and with it the bristles, still *in situ*, though mostly broken. On the rest of the body (leaving out of account, of course, the back, where the skin and soft parts were destroyed down to the bones) little more of the hairy coat was to be seen. The pieces of skin hanging to the sides on the right and left showed traces of the hairy coat only on a few protected places. On the protected underside the skin was most nearly intact. But here also on the skin of the belly the hair was nowhere still fast. The covering of woolly and bristly hairs, which was here abundant, could be collected only after the separation and removal of the carcass from the loess and the ice strata in which it had been frozen.

The destruction of the soft parts of the head and back above mentioned were due to the imperfect provisional safeguarding of the carcass before the arrival of the expedition. The carcass, which was bought by the Koblymsk Cossack Javlovski from its Lamut discoverers as a speculation, after he had inspected it, was covered again with earth and stones and so left to its fate on the "taiga" for many months. The consequence of this mode of safeguarding was that wild beasts partially destroyed the soft parts, and climatic influences also did great damage. A much more durable temporary protection against wild beasts and the weather, and one guaranteed to afford security in the case of a valuable find, would be to erect a roughly-constructed blockhouse over it. The wood for the purpose, suppos-

ing that the find occurred within the tree limit, would certainly, in most cases, be available, and as all ivory hunters and other hunters, etc., always carry hatchets with them it would not be a hard task to make such a structure, and it could be set up by two or three men in a few days. If a find appeared sufficiently important to induce these people to report it, the prospect of a reward should cause them to follow instructions given them for its preservation.

My observations at the place of discovery of the Beresovka Mammoth and examination of the pieces of skin of the Adams Mammoth, as well as skin fragments from other earlier specimens preserved in the [St. Petersburg] museum, lead me to the belief that the long bristly hairs were distributed throughout the neck and body about equally as regards length and density.[a] It follows from this that the hairy coat of the mammoth had the closest similarity to that of the musk-ox. The mammoth, however, as little as the musk-ox, can be said to have had a mane on any part of the body, which by reason of the greater length of the bristly hairs extended beyond the surrounding hairy parts of the body. It is quite possible that the bristles reached a somewhat greater length on the breast and neck; they did not extend, however, beyond the long hair of the rest of the body in the form of a mane.

Brandt, in his description of the hairy covering of the mammoth, says "that the body, in confirmation of Boltunoff, Adams, and Tilesius, was clothed with long, thick hair, is demonstrated by the piece of skin brought back by Adams, which is to be found in the museum of the [St. Petersburg] academy, on which in two places—each some inches in diameter—firmly attached hairy covering was found intact."(?)[a]

Brandt remarks further in the same article that Boltunoff, who, as mentioned at the outset, saw the Adams Mammoth in a better state of preservation than did Adams, made no allusion to a mane in his description, while Adams, evidently misled by the long bristles found near the carcass, speaks of one, and thus first brought forward the theory of the presence of a mane on the neck and breast.

The drawings made by the ancient mammoth-hunters all show indications of a long hairy coat, not only on the neck and breast, but also long hair hanging from the sides and belly.

The bristly hairs of the mammoth reach a length of about 50 cm.

---

[a] According to the investigations of Möbius on a piece of skin of the Adams Mammoth preserved in the Berlin Zoological Museum, the distance between the wooly hairs amounts to 0.2 mm. at most, and between the bristles 4 to 5 mm. (See Möbius, "The hair of the mammoth and of the living elephants compared," in Sitzber. Berlin Akad. Wiss., 1892, p. 528.)

[b] Brandt, "Observations on the form and distinguishing characters of the Mammoth" in Bull. Acad. Sci., St. Petersb., 5, p. 579.

on the neck and body. The very thick woolly hair which forms the underfur has an average length of 4 or 5 cm. At the end of the entirely hairy tail were, in certain places at least, a number of long bristles a millimeter thick, which here formed a dense tuft.

The color of the bristles must have been rust brown originally, somewhat lighter or darker on various parts of the body. In the remains preserved, this hair has become lighter through bleaching, varying from dull fox red to fawn brown. The woolly hair varies from light fawn to yellowish brown.

The most essential distinguishing character of *Elephas primigenius*, and indeed of all proboscidians living and extinct, is found in the incisor teeth. Through the discovery of the Beresovka Mammoth the question of their position in the skull and of their curvature and the direction of the tips was settled in a most positive manner, as already mentioned.

FIG. 2.—Tusks of Beresovka Mammoth.

In the Beresovka Mammoth only one tusk — the left—was found, and this one, indeed, was no longer in place when the expedition arrived. The discoverer of the carcass had destroyed a portion of the upper alveolar wall by strokes of a hatchet and had then separated the tusk from the alveolus and carried it to Kolymsk, where it was stored away by the authorities. Upon fitting the tusk into the alveolus, it was immediately demonstrated that it belonged to our skeleton.

The reconstruction of the skeleton having been intrusted to me, I was able to convince myself that the original position of the tusk in the alveolus could be determined in an unquestionably correct manner by inspection of the hatchet strokes. The strokes by which the wall of the alveolus was cracked off had indented the surface of the tusk. If the latter, which was only broken a very little at the base, was thrust into the alveolus as far as the indentation of the uppermost transverse hatchet stroke visible on its surface (this place is

indicated by an *x* in fig. 2), and this indentation on the surface of the tusk fitted to the cut surface of the penetrated wall of the alveolus, the tusk was inserted as deep as it possibly could be. It then fitted in its alveolus like a dagger in its sheath, and even the smallest turning to the right or the left was impossible.

The two tusks, which stand with their bases at an acute angle with each other, after passing out of the alveoli first point downward, then curve outward and somewhat upward, and finally the ends turn inward. The worn surface (marked with an *a* in fig. 2) is found on the upper side of the tip, sloping both outward and inward. Tusks in an incomplete condition as regards development, such as those of the immature Beresovka Mammoth, which have as yet no pronounced spiral form, almost always have the worn surface on the upper side of the tips. Exceptions correspond with the greater or less degree of curvature, in which regard the tusks of *Elephas primigenius* offer numerous variations. Why the mechanical abrasion of the tusks in the stage of development represented in the Beresovka Mammoth are necessarily on the upper side of the tips I shall endeavor to explain later.

It follows from the position of the tusks of the immature Beresovka Mammoth that the points in this stage of development are normally bent inward (fig. 2).[a]

The spiral development of the tusks, which like all rootless teeth grow steadily from the base until they reach complete development, on account of the fact that the tips are first directed inward, leads finally to their curving downward. Such strongly developed tusks, with a curvilinear length of over 4 meters, are borne by the mammoth in my restoration. The distance between the tips reaches about 50 cm.

This position of fully-developed tusks makes at first, perhaps, a strange impression. The tusks of the Beresovka Mammoth already show some indications of the further development which occurs in *Elephas primigenius* through spiral twisting, but we have tangible proof of that development in various other tusks which are in a perfect state of preservation.

The tusks in my restoration are in exact reproduction of the two powerful specimens in the collection of the St. Petersburg Zoological Museum. They are both in perfect condition and show both the pulp and the tip intact. They illustrate in a typical manner the extraordinarily strong spiral curvature of fully-developed mammoth tusks, as their length from the base in a straight line is scarcely more than half their length along the curves. H. Pohlig describes these two

[a] See W. Salenski's work on the mammoth (in Russian), St. Petersburg, 1903, p. 84, pls. 24, 25.

tusks in his monograph on the Dentition and Craniology of *Elephas antiquus* Falk.[a] Strauch states that these two huge tusks were brought from the Kolyma River by the merchant Gromoff, and that they were "both found still sticking in the skull."[b]

The right tooth of this pair measures 2.25 meters from the base to the tip in a straight line; its length along the curves is 3.91 meters; its maximum circumference 90 centimeters from the base equals 46 centimeters; and its weight is 75¾ kilos. On the inner side 42 centimeters below the tip this tooth bears a rather flat, elongated, oval, sharply defined depression 19 centimeters long and 6½ centimeters broad, which, as Pohlig notes, was formed after the animal was killed.

The left tooth is the larger. It measures 2.12 meters in a straight line from base to tip and 4.16 meters along the curves; the maximum circumference is 90 centimeters at a point 48½ centimeters from the base. Its weight is 84⅓ kilos.

My measurements of the left tooth of this pair agree almost exactly with those given by Pohlig for the right (compare Pohlig's measurements, viz. 4.33 meters for the length along the curves and 0.9 meter for the maximum circumference at a point 0.49 meter from the base). On the other hand, the curvilinear length (391.5 centimeters) of the tooth described by him as "the other equally complete and entirely similar mammoth tusk of the same museum" (loc. cit., p. 323) corresponds with the curvilinear length of the right tooth which I measured. This remarkable circumstance I can only explain by the supposition that the measurements of the two teeth were interchanged in the monograph cited. That the teeth there referred to are the same that I am describing here appears from the fact that Pohlig gives as a peculiar mark of one, which he calls the right, the shallow saucer-shaped depression. Further, there existed in the museum no second tusk "just as complete and entirely similar" besides the one described by me above as the left, while these two absolutely similar tusks are a unit as regards size, completeness, and condition.

A still stronger spiral twisting in proportion to the direct length is shown in a tusk also to be found in the collection of the [St. Petersburg] Zoological Museum, which is likewise mentioned by Pohlig, and of which he gives two figures.[c] This tooth, which is a left one, is only 98 cm. long in a straight line, as against 1.59 m. around the curves. Its maximum circumference (60 cm. from the base) is 23.7 cm.

---

[a] Nova Acta K. Leop. Carol. Acad., Bd. 1, 7, pp. 321–322 (illustration in Pl. B, fig. 3).

[b] A. Strauch, The Fiftieth Anniversary of the Imperial Academy of Sciences of St. Petersburg, p. 331.

[c] Page 322 of the monograph previously mentioned, Pl. B, figs. 4, 4*a*.

This tooth is very well preserved. From the alveolar part a portion about the pulp wall of not more than 5 cm. in length is broken off. The conical top of the pulp cavity, about 6 cm. deep, is still present. From the tip a small piece is broken off. Of this very interesting tooth I give a figure showing the outer surface from the side, with an indication of its position in the skull (fig. 3*a*), and also a view from in front (fig. 3*b*).

As it is an important point in my exposition relative to the position and direction of fully developed (or, in other words, strongly spirally twisted) mammoth tusks in the alveoli, I must insist that the smaller left tusk described above can not, as Pohlig asserts, be a right tusk. Its position in the alveolus as a right tooth is entirely inconceivable, and, besides, its entire form and curvature show that it is a left tooth.

During my journey in Siberia I saw many larger and smaller fragments of shorter and hence still more strongly spirally curved mammoth tusks in the stock of Russian and Yakutsk traders in fossil ivory. The smaller tusks, which are easy to transport, are mostly brought in entire to these traders by the ivory collectors, while the large tusks, on account of being difficult to transport, are commonly cut up where found.

FIG. 3*a*.—Tusk of mammoth in St. Petersburg Museum.

The abraded surfaces (marked "a" and shaded in the outline of the right incisor in fig. 3*b*), are found on both the large tusks represented in my restoration, as well as on the exterior of the last-described smaller tusk—that is, on the front of its ends, running right and left. They include almost the whole anterior face of the downward-directed portion of the tusk. In the two large teeth the abraded surfaces measure from the tip upward about 120 cm. On the left tusk of these two, on the anterior side of the end, directed somewhat inward, an original abraded surface is recognizable, 30 cm. long and 7 cm. broad at the middle. It has been gradually worn away by the newly-made second abrasion at the downward-curved tip of the tooth, and in the right tooth of this pair has already entirely disappeared. The small original abrasion, such as that found on the upper side of the end of

the tusk in the Beresovka Mammoth, as well as the secondary more extensive abrasions, could have only arisen through the circumstance that the animal used its developing tusks, and later the downward-directed tips, for detaching its food. While for a large part of the year ice and snow covered its northern feeding ground, it could, by means of its tusks, dig up out of the snow its food, consisting mainly of grasses and higher plants, shrubs, etc., and indeed in wandering about,

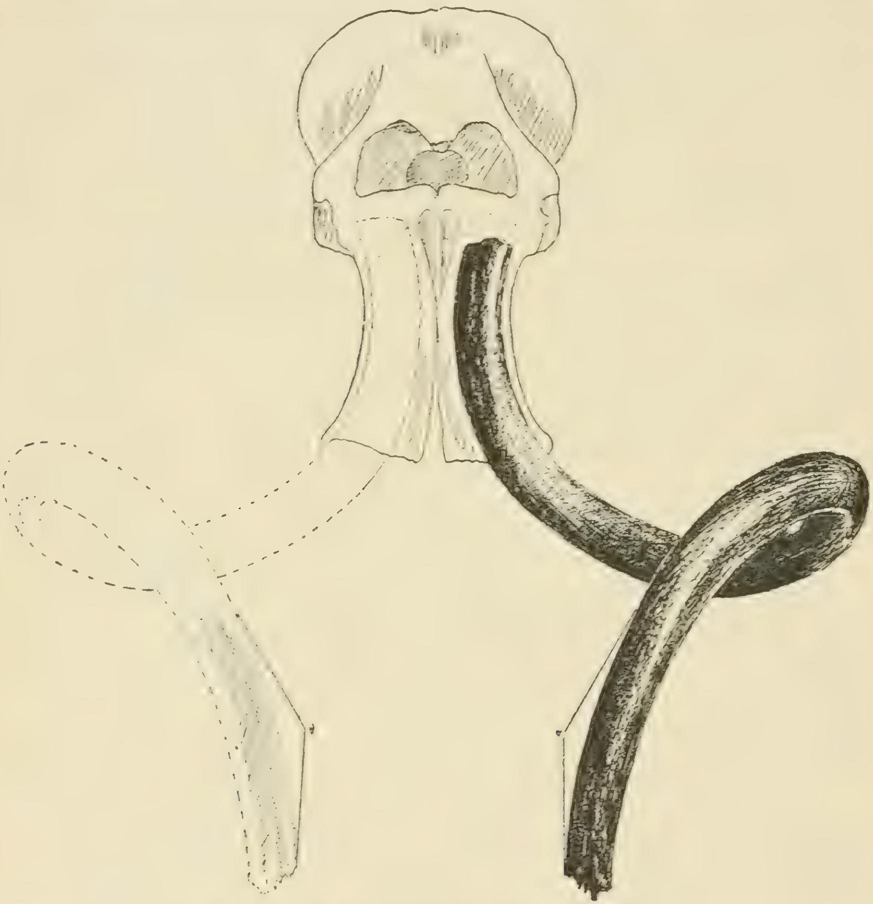


FIG. 3b.—Tusk of mammoth in St. Petersburg Museum.

tossing and scraping away the snow and ice with its tusks, it collected its food together and then took it in with its trunk. I often witnessed the same among the tame reindeer, which at this time of year beside freeing their food with the front hoofs also in similar manner by strokes and scraping with the downward-directed shovel-like brow-tines of their antlers. The lower ends of these brow-tine shovels were abraded through their use in snow and ice, mixed with stones, sand, etc., and the harder the antlers the more they were

abraded. It is obvious that the mammoth could only reach the ground with the ends of its tusks if they were placed as indicated in my restoration. How could the abrasion surfaces arise, which are formed very gradually in the later, far-advanced stages of development, if fully developed tusks had the direction they were formerly supposed to have—that is, projected up into the air in a semicircle? (See the figures of the Adams Mammoth skeleton.) In such a position the tusks would be entirely useless ornaments, while, if placed as they really were, besides their above-described use the animal had in them also a powerful weapon. It is, moreover, not doubtful that

FIG. 4.—Cranium of mammoth in Cracow Museum.

to the almost continuous use of the tusks as digging implements, which use was only interrupted during the short northern summer, is due their powerful development, and also especially the direction of the tips.

After the preparation of my restoration I received an extremely instructive photograph of a mammoth cranium, which is in the museum of Cracow University. This cranium was found in 1851 at Bzianka, in the neighborhood of Rzeszow, in West Galicia, under the loess.[a]

This photograph (fig. 4) shows the cranium from in front. The

[a] Jahrbuch der geol. Reichanstalt in Wien, 2 Jahrg., IV Vierteljahr, p. 158.

curvilinear length of the complete left tusk (the shorter right one is broken) is almost exactly 200 cm.; its circumference at the place where it leaves the gum is 30 cm. Its direct length is 157 cm., wherein it is seen that the spiral twisting of this tusk is much less than in the shorter left tusk described above, which is in St. Petersburg. Its position and direction, however, confirm fully what I have maintained above.[a]

The tusks belonging to the Adams Mammoth skull, as well known, were sawn off at the place of discovery, with destruction of a part of the alveoli. On the stumps of the original tusks, when the skeleton was set up, were placed other tusks without the alveolar part, which were made up of different pieces not belonging together. The right tusk consists of three pieces and the left of two pieces. The edges of the pieces where they were joined were planed off and the surface stained to agree with the rest. The tusks "restored" in this manner correspond neither in size, length, direction, nor curvature with those which this huge individual originally carried, nor especially with complete, fully-developed tusks, and can not have the proper direction. That these tusks are made up appears not to have been noticed before, for Brandt writes in his "Remarks on the form and distinguishing characters of the mammoth:" "That the tusks placed in our mammoth skeleton by Adams (which were bought in Yakutsk and show no traces of artificial separation) do not belong to it, appears from their less breadth in comparison with the basal parts of its own proper tusks which remain in the skull." Pohlig, who was in St. Petersburg in 1890, and examined the Adams Mammoth skeleton, remarks in his monograph, already many times referred to (pp. 323, 388), that the tusks are not only an addition but that they are not a pair and belonged to a much less powerful animal. Regarding their being made up of different pieces, which is most important, he says nothing.

The Adams Mammoth skeleton was first made known through Tilesius' figure (see Mém. Acad. Imp. Sci., St. Petersbourg, 5, 1815, pl. 10), which represents it with the tusks curving upward and outward, and with the tips directed toward the shoulders, as they remained until the recent dismounting. Cuvier, in his "Researches on fossil bones," repeats Tilesius' figure (Oss. foss., pl. 11, p. 174) and says regarding it: "The tusks of the Adams skeleton, to judge by the figure, were 12 feet 7 inches long" (p. 174), and further "it appears that the tusks were in general large, often more or less spirally curved and directed outward" (p. 200). The

[a]At my request Professor Szainocha, of Kracow, had the great kindness to send me the photograph and measurements of the cranium and to permit their reproduction.

restored condition and false direction of the tusks of the Adams Mammoth skeleton were unrecognized by Cuvier, to whom it was known only from a drawing. By the reproduction of Tilesius' drawing in his celebrated work, the same was made known to, and distributed throughout, the world, and thereby false ideas regarding the tusks of the mammoth were disseminated. For wherever a picture of a mammoth skeleton is desired, a copy of the drawing above mentioned is always to be found.

The discovery of the Beresovka Mammoth, which helped to clear up the misconception regarding the position and direction of the tusks, is, therefore, so much the more important. It is quite certain that some one will yet be fortunate enough to find in the Siberian Far North a skull of *Elephas primigenius* with fully developed tusks still in their original position, and preserve them for science; and I believe such a discovery will establish positively my views as here given.

The knowledge of the exterior of the mammoth is, through the carcass brought to light at Beresovka, if not carried to finality, at least extended in an important degree. The completeness of the discovery was thwarted, as above mentioned, principally by the insufficient protection afforded by the provisional shelter of the body. Thereby a large part of the hairy covering of the epidermis was detached, a part of the back and all the soft parts of the head were destroyed, particularly the characteristic organ of the proboscidians—the trunk—a part of which was, however, found by the original discoverer. Yet, through the Beresovka Mammoth, many deficiencies and many errors in our knowledge of the morphology of *Elephas primigenius* are corrected, and we are placed in a position through this discovery to make a more nearly accurate picture of this fossil elephant than was possible previously.

HEREDITY.[a]

By L. Cuénot,

Professor at the University of Nancy, France.

The subject which I have with some temerity chosen is far too vast to be treated in a single lecture, so you must not reproach me with being incomplete; I must voluntarily choose to be so.

From time immemorial observers have been much impressed by the resemblance which children bear to their parents; from the latter to the former there is a transmission which is certain, although capricious, appearing to obey no law, and sometimes affecting quite insignificant details which are reproduced with striking fidelity. This fact of transmission is known as *heredity*.

Before taking up the study of heredity, it is necessary to recall how a new individual, whether of animal or plant, is formed. Let us take, for example, a hen and a cock; in the interior of the body of the female there is found an organ, the ovary, in which ova are formed, which you know under the name of yolk of egg; in the male two testicles form little microscopic elements, called spermatozoa. As a result of the sexual union of the two individuals a spermatozoon comes in contact with the ovum and unites with it; this is the precise act that constitutes fecundation. The fecundated ovum, enveloped with an albuminous coating, the white, with a membrane and with a shell is laid or deposited outside the body of the hen and later develops into a little chick. Now, this chick, when its growth is completed, will present certain characters that are identical with those of the father and others identical with those of the mother; from the one he may derive, for example, a peculiar form of comb; from the other the color of the feathers, etc. It may also be said that in spite of the disproportion of size between the egg and the spermatozoon neither one of the two parents shows any visible predominance in the transmission of characters; there is then in each sexual element, in corresponding equivalent quantity, a substance that con-

[a] Translation, by permission, of a public lecture given March 17, 1906, at the University of Nancy, under the auspices of the Réunion Biologique, printed in the Revue Scientifique, Paris, April 28, 1906.

tains the potency of the hereditary qualities. This material substratum of heredity is termed the *germinative plasma* or *germen*. The two sexual elements, ovum and spermatozoon, equivalent as to their possession of germinative plasma, are *gametes* (from the Greek *gamos*, marriage) and the product of their fusion is a *zygote* (from the Greek *zygo*, to yoke or join together).

I call especial attention to the fact that the substance of the new individual is the sum of the two germens derived from its parents. Now, there is no doubt but that our qualities and our defects depend upon our material structure. If the gametes are potent with health and intelligence, the zygote has chances of being healthy and intelligent; if the gametes are potent with idleness, insubordination, etc., the zygote will probably be idle and disdainful of authority. Education and the influence of the environment may perhaps modify this heredity, but to what extent, we may ask. We here touch upon the grave and difficult question of moral responsibility, a problem which often comes up before courts of justice and before society, and which we are obliged to admit is solved in an unsatisfactory manner, but little in accord with the strict teachings of biology and with the properly understood interests of human social groups.

For a long time observers confined themselves to showing that characters of all sorts were transmitted, and to registering facts, observations of breeders, peculiarities of well-known people. For example, there was noted the transmission in the Hapsburgs of a prognathous lower jaw, accompanied secondarily with an exaggerated development of the lower lip—the Austrian lip, as it is called—quite marked in the present Emperor of Austria, in Alphonso XIII (Hapsburg by his mother, Maria Christina, daughter of an archduke of Austria), and many others; heredity of stature, of certain diseases, of longevity or shortness of life, etc., were observed. There were also noted at the same time apparent caprices in heredity. A number of observed facts are found in the books of Darwin and also in those of Lucas, whose ideas Zola ascribed to his Doctor Pascal in the well-known novel that concludes the Rougon-Macquart series.

It was felt, however, that under this chaos there must be laws. An endeavor was made to discover them by collecting and analyzing statistics in considerable numbers, extracted for the most part from books recording the genealogy of dogs and race horses. An attempt was made to deduce from these statistics the frequency with which a given character is inherited, or, in other terms, to determine the proportional influence which the different ancestors of an individual have upon his characteristics. This so-called "biometric" method has indeed furnished an approximate law—the law of Galton—but it has not fulfilled the expectations that were based upon it. Since the statistics confound under one designation, forms which may be pro-

foundly dissimilar from the point of view of their hereditary value. the results are necessarily erroneous.

Finally, however, the application of the experimental method at once revealed precise laws which threw a bright light upon the phenomena of heredity. It is necessary that I should detail with some care the fundamental experiment figured in the diagram (fig. 1).

You are acquainted with the wild gray mouse on the one hand and the white or rather albino mouse, which can be readily procured of dealers in animals, on the other; these two forms differ sharply from each other; the gray mouse has colored hair and black eyes; the white mouse has pure white hair and pink eyes, that is to say it is lacking in coloring matter. We may take these two forms for the purpose of investigating the laws of heredity as regards these two complementary characters, that is, as regards the presence or absence of color.

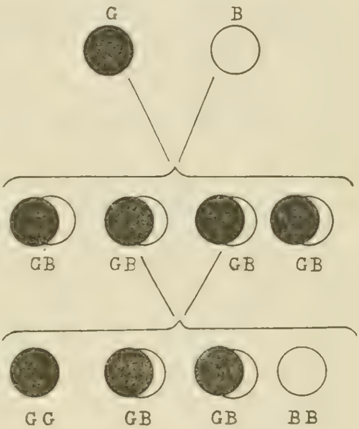


Fig. 1.—Diagram of a crossing between a gray mouse (black circle) and a white mouse (white circle). The covering of two-thirds of the white circle by the black one indicates that in the hybrids the gray character is dominant.

The crossing between these two forms constantly furnishes offspring absolutely like the gray parent with black eyes: there is no mixture between the two complementary characters, no mixed form; it is the gray parent exclusively that reappears in the progeny; it is then said that there is a *dominance* of the gray character; the white character which is not expressed, which is hidden by the other, is said to be *dominated* or *latent*.

But let us continue the experiment; let us cross with each other the hybrids having the dominant gray character. There appears this time in the progeny some gray ones still, but there are also white ones with red eyes, the latter being less in number than the former. If a considerable number of crossings has been made so as to have some hundreds of specimens, it will be seen that there is always a fixed numerical relation between the two kinds, a relation which is that of *three* grays for every *one* white.

This experiment must now be interpreted. The following hypothesis has been advanced with regard to it: The progeny of the first generation, those which were all gray, were formed by the fusion of a gamete including a potency of the gray character with another gamete including a potency of the white character; now these two potencies pass into all the cells of the body, including the genital

cells of the ovary and the testis. At the moment of the formation of ova and spermatozoa, for some unknown reason, the two potencies can not remain longer in the same cell; they separate from each other; there is, as is said, a *disjunction of characters*. Half of the gametes receive the gray character (G), the other half the white character (B). When these hybrids are crossed with each other there may consequently be produced four combinations of gametes:

Gray × Gray (GG)
Gray × White } (GB)
White × Gray }
White × White (BB)

These four combinations will give the following results:

Gray × Gray = Gray of pure race.
2 { Gray × White } = Gray of impure race, similar to the hybrids of the first generation.
  { White × Gray }
1 White × White = White of pure race.

We may express this result in a briefer form by saying

$$GB \times GB = 1\,GG + 2\,GB + 1\,BB,$$

which corresponds to the results of the experiment.

On the other hand, we may verify, one by one, the mice produced and see that everything conforms entirely to the theoretical explanation. The diagram (fig. 2) shows one of these verifications. By crossing a gray mouse of impure race, which includes the white in a dominated state, with another white mouse, there is obtained this time *as many* whites as grays. In fact, because of the disjunction of characters the mixed hybrid produces as many gametes having a gray character as gametes having a white character. The white mouse naturally possesses only gametes having a white character. There are, then, only two combinations possible—

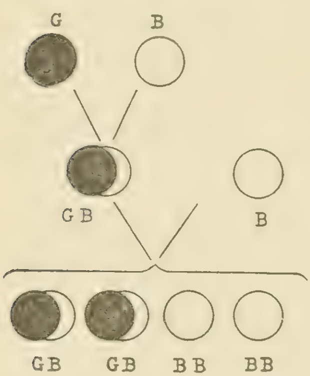


Fig. 2.—Diagram of a crossing between a gray mouse possessing the white character in a latent state and a white mouse. The progeny show an equal number of grays and whites.

Gray × Gray = Gray of impure race (GB).
White × White = White of pure race (BB).

Then—

$$GB \times BB = 1\,GB + 1\,BB.$$

The experiments, very long and often quite delicate, give results so much in conformity with the theoretic anticipations that it is evident that the hypothesis represents the real conditions. It has been proved that this curious phenomena of the disjunction of characters, *resulting in the purity of the gametes*, is

extremely widespread, both in the animal and the vegetable kingdoms. We are now acquainted with a large number of characters, very different from each other, that follow the hereditary law that I have just explained. We find, what seems at first rather paradoxical, that a man has just as many chances of transmitting to his children the dominant characters visibly expressed in him as the latent characters he may possess.

This fundamental experiment in the history of heredity was made quite a long time ago by an Austrian monk named Johann Mendel, also called Gregory Mendel (Gregory being his monastic name). The sagacious interpretation which he gave remained, however, unappreciated for more than thirty years and exercised no influence upon the theories of heredity advanced during that period. Weismann, without any doubt, would have made much use of the Mendelian hypothesis and its consequences, to moderate and modify his celebrated theory.

Johann Mendel was born in 1833 at Heinzendorf, in Silesia. His father was a peasant who was particularly interested in the culture of fruit trees and who did not fail to take his son with him when he went to care for his nursery. His uncle was a self-made man, well informed, and, it would appear, very intelligent. Mendel, after his studies at the gymnasium at Troppau, entered at Brünn, in Moravia, a convent of Augustine monks, which was surrounded by large gardens. There he finished his theological studies and was ordained a priest; he was then sent, at the expense of the convent, to the University of Vienna, where from 1851 to 1853 he pursued courses in mathematics, physics, and natural sciences. He was soon appointed professor at the technical school at Brünn, where he remained for fourteen years; in 1868 he became the superior of the Augustine convent. It was during the period of his professorship that he made experiments in the convent gardens in hybridization with peas and beans. He published his first notice in 1865 in a publication having a limited circulation, the Bulletin of the Society of Naturalists of Brünn, where it remained buried; also a second notice in 1869. With admirable clairvoyance, especially considering the period in which he was working, he completely defined the law of heredity to which his name is justly attached, escaping the attention of the French naturalist, Naudin, who was working on the same subject at the same time, and who merely suspected the existence of the phenomena of disjunction.

Mendel also experimented with the crossing of bees, but his experiments were not finished and his notes have been lost. Unfortunately for science, various administrative employments took up the greater part of his time; besides his office as superior he was ap-

pointed director of the Loan and Trust Bank of Moravia. He was finally completely turned aside from his researches by the law of 1872 concerning religious communities, which, by this law, were obliged to pay an additional tax, that amounted in the case of the convent of Brünn to 5,000 florins per annum.

Mendel, who was very headstrong, fought to the end of his life against this law, which he considered unjust, and which was, in fact, quietly repealed a short time after his death by another ministry. His health began to fail about 1874, perhaps under the influence of a chronic nicotism. He had acquired the habit of smoking very strong cigars, a practice which had been recommended to him by a physician, to reduce his obesity (hereditary in his family). He died in 1884, at the age of 64, from Bright's disease.

The sagacious discovery of Mendel remained then unnoticed. About 1900, more than thirty years afterwards, certain biologists undertook in their turn, independently of each other, some experiments in heredity. De Vries (Amsterdam), Correns (Tübingen), and Tschermak (Vienna), operating upon plants, rediscovered the law of Mendel and brought to light his work. In the zoological field, Bateson (Cambridge), experimenting with domestic fowls, and myself with mice, showed that the law applied to various characters of animals. Since that time numerous works have appeared, and the list of characters that, in the most varied animal and vegetable groups, follow the law of Mendel, has been considerably augmented. It formulates a type of heredity, which is the most frequent of all, and it may be the only one.

It should not be supposed that it is always easy to demonstrate the law of Mendel, as has been done in the example cited above. In that only two characters were taken (G and B), and these were opposed to each other. There are, however, other races that differ from each other, not by one germinal character alone, but by several, independent of each other, some of them being dominant, others dominated as regards complementary characters of the opposite race. The crossing of hybrids then gives such complicated results that the application of the Mendelian laws is not readily perceived.

For example, let us examine another diagram (fig. 3), more complicated than the last, in which is shown the scheme of the crossing of two races of mice whose germinal plasma presents *three* differential characters, which may be put in evidence by patient analysis.

I cross a white mouse with red eyes with another mouse also having red eyes but with yellowish brown hair; it is logical to suppose that the descendants will have red eyes like the parents, and that their hair will be either yellow or white; now, this is not at all what hap-

pens; the result is quite different and rather paradoxical: the descendants of this union all have black eyes, and gray hair upon the back and white upon the belly; besides, their eyes are undoubtedly larger than those of their parents. Their characters, on the whole, markedly resemble, not at all the gray house mouse (*Mus musculus*), but the field mouse (*Mus sylvaticus*). Instead of presenting the phenomenon of dominance, the parental characters have *combined* to produce a new result, a first difference from the Mendelian type described above. I then cross the pseudo field mice resulting from this combination. This time there is obtained an extraordinary variety of forms: First, mice that are wholly black; second, gray mice with white bellies, like their parents; third, white mice with red eyes, like one of their grandparents; fourth, yellow mice with red eyes, like one of their grandparents; fifth, light gray mice with red eyes. These five forms present fixed numerical relations, which appear to be as follows: In 64 offspring we find:

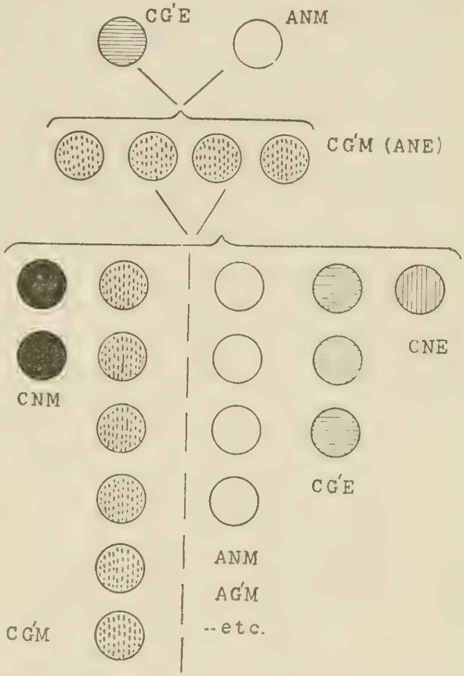


FIG. 3.—Diagram of the crossing of a white mouse (white circle) and a yellow mouse with red eyes (circle with horizontal shading). The hybrids (atavistic forms) resemble the field mouse. The crossing of these hybrids produces black mice (black circle), gray mice with a white belly (circle with dots), white mice (white circle), yellow mice with red eyes (circle with horizontal shading), and light gray with red eyes (circle with vertical shading).

36 with black eyes	9 black. 27 gray, with white belly.
28 with red eyes	16 white. 9 yellow. 3 light gray.

It would take too long to explain to you in detail what has happened, but I may say that everything here is merely an application of the Mendelian laws, operating upon three pairs of antagonistic characters; new combinations have naturally been formed, and these have resulted in the production of unexpected forms, the black and

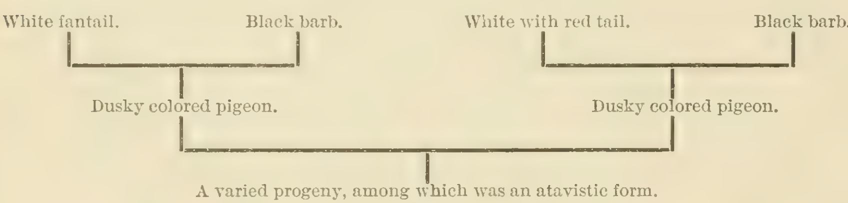
the light gray, and in the combinations already known that reproduce the types seen in the parents and grandparents.

This second type of heredity is particularly interesting to horticulturists and breeders. It is probably crossings of this kind that, in the second generation, when the plant *breaks*, as the horticulturists say, produce new varieties comparable to these black and light-gray mice, that may be superior in value to the primitive parents.

It is possible that there may be other laws of heredity than those of Mendel, but as the work of investigation proceeds the less this seems likely; in any case, we do not as yet know any absolutely certain example. I will not dwell, therefore, upon this aspect of the subject.

The explication of Mendelian heredity has had numerous theoretical consequences. A number of facts that were very difficult to explain have become quite clear: this is notably the case with atavism (from the Latin *atavus*, an ancestor).

Atavism is a singular phenomenon which consists in the unexpected appearance in breeds of animals or plants of a form (atavistic) that recalls in whole or in part an ancestor that disappeared a number of generations ago. As a first case I will recall the classical example given by Darwin. He crossed well-marked and constant breeds of pigeons, two black, a white with a red tail, and a white fantail, and at the second generation obtained, among others, a magnificent blue pigeon with white croup, double black wing bars, tail barred and bordered with white—in fact, having every characteristic mark of the rock pigeon, the wild *Columba livia*, which is almost certainly the ancestor of our domestic pigeons. The following diagram will show the details of the crossing:



I described to you a few moments ago a crossing which certainly furnished atavistic forms. I refer to the crossing between white mice and yellow mice with red eyes. These two forms, that breed with perfect constancy, have each had parents identical with themselves for many generations, and yet the products of their union are all mice identical, or nearly so, with the field mouse, which is probably closely related to the wild ancestor of our house mice.

In order to explain this reappearance of an ancestor, Darwin and Weismann, to cite only them among many others, have greatly complicated their theories of heredity. They have thought it neces-

sary to admit that a fragment of the germinative plasma of the ancestor has been preserved, latent for years, perhaps even for centuries, until the day when by reason of favorable circumstances this fragment succeeds in becoming isolated in a gamete and in becoming predominant, so as to reproduce the ancestral form. The matter is much more simple than that. There is no latent ancestral fragment; there is nothing that represents any of such ancestors in a germinative plasma any more than there is in carbonic acid and lime any representative of the limestone from which they were formerly extracted. If the ancestor reappears under certain circumstances, which one can reproduce at will, it is because the union of two different germinative plasmas has formed a combination entirely identical with the germinative plasma of the ancestor in the same way that by uniting carbonic acid and lime we succeed in re-forming limestone.

The interest of these studies of heredity is not confined to pure science alone. Heredity as a factor has such considerable importance in history, in sociology, in our own personal development, that it may often be of use to us to understand its laws. We may, to a certain degree, predict our own future and that of our children, and as this is only a prediction of probabilities there can be nothing unreasonable in doing it. If the prevision is disagreeable, there is always the hope remaining that a favorable probability may intervene.

For example, there is no doubt that the duration of life, depending as it does upon the structure of our organism, is markedly hereditary. We may cite the case of Turgot, who at 50 years of age put his affairs in order, although he was in vigorous health, knowing that in his family the fiftieth year was rarely exceeded. He died at 53. Centenarians invariably have had parents of great age. It must, of course, be understood that such transmission of the duration of life is merely a probability, and also that it rests upon the condition that our mode of life is fairly analogous to that of our ancestors. Naturally an accident or a contagious disease may cause death before the time fixed by heredity, but this is not the fault of the latter.

It is possible that certain diseases, or, to be more exact, certain diatheses or morbid tendencies follow in their heredity the laws of Mendel, so it is said that cancer is hereditary in the proportion of 1 to 6 or 9. It is then quite probable that there is in the gametes a disjunction between the normal state and this pathological character. I will cite a celebrated example of its transmission: Charles Bonaparte, the father of Napoleon, died at the age of 39 of cancer of the stomach. Among his eight children one alone, Napoleon, was stricken with the same disease when 50 years of age.

In the same family there is a fine example of dominance. The

Hapsburg characters completely dominated those of Napoleon so that l'Aiglon, the Duke of Reichstadt, was as typical a Hapsburg as possible.

(See the succinct genealogy below.)

Hapsburg. Spanish Bourbons.

CHARLES BONAPARTE. (*Cancer.*)

LÆTITIA RAMOLINO. (*Healthy.*)

FRANCIS II OF GERMANY. (*Large lower lip.*)

MARIA-THERESA-CAROLINE OF BOURBON. (*Large lower lip.*)

NAPOLEON I. (*Cancer.*)

MARIA-LOUISA. (*Large lower lip, latent tuberculosis.*)

DUKE OF REICHSTADT.

(*Prognathism of lower jaw, large lower lip, tuberculosis.*)

We may say that the history of reigning families might be characterized as a record of experiments in heredity, experiments that are often unfortunate for them.

In conclusion, let me give you some advice: Almost everybody has visible defects or pathological latencies, the latter as important as the former as far as regards their transmission, as we have seen. If you wish that your children should be as far as possible free from these, avoid marriage with families presenting defects or latencies analogous to your own. I am quite aware that it is much easier to give this advice than to follow it. Man, who has for centuries practiced selection in the case of his domestic animals, has not yet realized that he might use it with advantage for his own descendants; yet robust health and a sound hereditary constitution are worth more than a large dowry, you may well be assured.

HEAD OF BISON OF THE CAUCASUS.

THE BISONS OF THE CAUCASUS.[a]

By A. Yermoloff,
Correspondent of the Institute, formerly Minister of Agriculture in Russia.

The bison problem is one of the most interesting in zoology, first, because it concerns a species—a very fine one—which would already have totally disappeared if special precautions had not been severely maintained to preserve its last representatives; second, because the prehistoric tracings and paintings of bisons found in certain caverns (at Altamira, Spain, in the Pyrenees, and in Perigord) raise many questions which have not yet been settled as to the exact epoch when those primitive, artistic representations were produced.

Twice within a short time articles have appeared in La Nature concerning the American bison (M. de Varigny, No. 1653, January 28, 1905) and the bison of the Caucasus (M. Forbin, No. 1723, June 2, 1906). It seems to me a proper occasion to complete, or perhaps to rectify, what was then said concerning the European bison (*Bonasus europæus*), particularly as I obtained special information on this subject during my official administrative work in the Caucasus.

I can guarantee the absolute accuracy of all the facts which I am about to cite, for they were communicated to me by the master of the hunt of the Grand Duke Sergius Michailowitch, who possesses vast "hunting grounds" (game preserves) on the north slope of the Caucasus range. There the European bison still exists in perfect freedom. In forests more primeval and of greater extent than those of Bielowitza (Lithuania) the Grand Duke Sergius has, indeed, preserved these animals from imminent destruction by man, by wild beasts, or by the natural conditions of a country where they sought a last refuge after the destruction of the great forests of central Russia; for the bison fled before the advancing settlements of man, whose proximity he could not endure.

I wish to state that I have the kind permission of the Grand Duke Sergius Michailowitch, one of the most experienced hunters in Europe, to use the report which he caused to be sent me by M. Ed.

[a] Translated, by permission, from La Nature, Paris, March 30, 1907, pp. 278–283.

Hutner, his master of the hunt, concerning the life and habits of these animals, so little known, so rare, and so difficult to observe when at large, and which, it was mistakenly believed, had forever disappeared from this region.

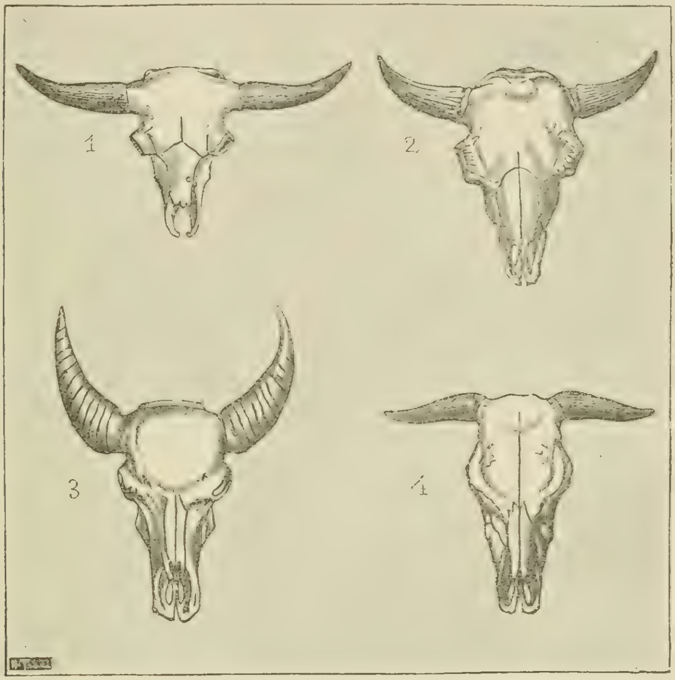
It is true that the bison is no longer seen in the western valleys of the Caucasus, between Sotchi and Sukhum. There is, however, every reason to believe that it never lived there even in ancient times. The rare examples reported by Doctor Raddé were not indigenous to that region, but descended from time to time from the principal range of the Caucasus when the snow was extraordinarily deep, or when pasturage was lacking upon the northern slope of the range, which was their true habitat; there their number not only does not tend to diminish, but increases from year to year, thanks to the measures of protection taken by the Grand Duke Sergius. Thus, according to the report of M. Hutner, while their number twenty years ago was estimated as 400 head, there are at present at least 600. During this time the Grand Duke has organized, at his own expense, a complete service of game wardens, and, as he is the only one who has hunted the animals, there have been killed, for purely scientific purposes, to supply the various museums of the Empire, only 12 specimens, and these, too, were old animals, useless for breeding.

In the forest of Bielowitza (Lithuania), where the number of bison can be more accurately ascertained than in the almost inaccessible valleys of the Caucasus, there are supposed to be to-day at least 700 head.[a] Thus in these two localities alone there is a total of 1,300 head. On the other hand, according to the statement of M. Forbin, there is a total lack of bison in the virgin forests of Siberia, no trace of these animals having ever been found there.

Zoologically the Caucasian bison is quite identical in race with the bison of Bielowitza, although one lives in the northwest and the other at the southern limit of European Russia. The anatomical characters and bodily conformation of the bison show that it is not naturally an inhabitant of the mountains. During the middle ages it pervaded the great forests of Germany, Austria, and Poland, and even in France it was pursued in the Ardennes at the time of the Roman conquest. By constantly and desperately fleeing before man, retiring toward the south, the bison has found in the Caucasus a refuge, not very suitable, but safe, on the slope of mountains which were for a long time inaccessible, and which were, in fact, closed to the Russians until the last fifty years, not only because of the topographical difficulties, but also because of the wars with the Tcher-

[a]According to a census made in the month of March, 1906, the number of bison in the forest of Bielowitza was 663, but this was before the time of calving, which takes place in the months of April and May.

kesses and other aborigines, which lasted until about 1860. This is why, for a long time, the earlier explorers, notably Pallas, who merely penetrated to the borders of these regions, found only the bones of the bison, and therefore supposed it to be extinct. Still an author of the seventeenth century, Archangelo Lamberti, speaks of the survival of the Caucasian bison. The Russian naturalist, Behr, received in 1836 a bison skin from the Caucasus, by means of which he was able to determine the species and to establish its identity with the *Bonasus* of the north of Europe. In 1864 the skin of a young bison was sent to the museum of Tiflis; and this superb museum,



1. Ursus (Aurochs). 2. Bonasus (Bison). 3. Buffalo. 4. Domestic ox.

established and for a long time directed by the learned Doctor Raddé, under the auspices of the former viceroy of the Caucasus, the Grand Duke Michael Nicolaevitch, has also the glory of possessing the first and the finest specimens of adult animals discovered in these regions.

Nevertheless, the bison is distributed in the Caucasus over a very limited area (about 2,000 sq. miles). The region preferred by them is about the sources and upper portion of the Bielaja and the Malaja Laba (the White or Grand and the Little Laba), as well as their affluents, at the foot of the Shougous and Abagua mountains. To the north of this region stretch the communal forests belonging

to the Cossacks of Kouban. The animals that straggle beyond these limits are sure not to return, for they are pitilessly destroyed by poachers, despite the severe penalties that such offenders incur. In summer, and especially at night, the bison keep upon the Alpine pastures of the high mountains; during the day they descend into the deep, wooded valleys that are found along the water courses. They may be seen in bands of from four to fifteen, especially around the sulphurous springs that abound in that country. The mineral water of these springs seems to attract them particularly, for they remain for hours near them. Monsieur Hutner states that they avoid drinking from the springs in order not to disturb the water, and that they content themselves with licking the stones about the margins moistened by the waters and covered with a mineral deposit. Not only do the bisons refresh themselves in this manner, but deer are often seen about the springs, neither species interfering with the other. In the summer the deep valleys offer to the bison a refuge from the rays of the sun as well as an abundance of food, for these animals are very fond of the bark of certain forest trees, such as the *Sorbus acuparia* and the elm (*Ulmus campestris*), as well as the young shoots of ferns. But their principal nourishment is furnished by the rich and succulent grasses of the alpine pastures, to which they return at the approach of night. As to the dry forage which is given to the bisons of Bielowitza during winter, it is disdained by those of the Caucasus even during that season, in spite of the hunger that oppresses them, but they are very fond of the blocks of rock salt placed here and there for them.

The neighborhood of the Black Sea renders the northwestern part of the Caucasus very humid, and the rains of spring and summer, which are often like floods, favor the rapid growth of herbage on which the bison regale themselves during the hot season. By this means they grow strong and store up considerable quantities of fat, which enables them to endure the rigorous months of these high altitudes. Besides, the bison, being a northern animal, does not fear the cold, against which he is fortified by his thick coat of hair, so that he does not perish from either hunger or cold, but he suffers from another scourge, the heavy snows that often attain a depth of several meters and sometimes cannot support the heavy weight of the bison and the animal sinks in, is unable to extricate himself, and soon suffers a premature death.

After the exceptionally heavy snows of 1904 and 1905 there were discovered, in the spring, nine cadavers of bison that had sunk into the snow without being able to reach with their feet either the firm ground or a more compact layer of snow. Against this cause for the diminution of the species no protective means can be devised. More

than this, after very snowy winters those animals that live through to the spring are very weak and thin and there are almost no calves with the females. The greater number of pregnant cows, weakened by struggling in the midst of the snow, have not carried their offspring to maturity. On the contrary, during the years when the snow is less abundant there are a number of normal calves found in the herds.

It is affirmed that the combats between bulls, so frequent at Bielowitza, have never been observed here. At the time of calving generally in the month of March, the pregnant cows abandon the herds and seek isolated localities, usually on the confines of the alpine region, hide themselves in the midst of the thickets at the edge of the forest, often in the almost impenetrable masses of rhododendrons, and there bring forth their young. A cow has never been known to give birth to more than one calf. Six or seven days after birth the offspring is strong enough to follow its mother. On meeting man the cow does not defend her young, but flees, abandoning it to its fate as soon as man attempts to approach. The German naturalist, Brehm, reports that the mother cow kills her own calf if she discovers that it has been touched by the hand of man. I do not know that anything of the kind has been observed in the Caucasus, but everything goes to prove that the bison considers man as its most dreaded enemy, abhors his presence, and flees from his approach as far as the region of the glaciers. The bison has also much to dread from the wild beasts of different kinds that abound in the forests of the Caucasus—from the panther, which is becoming more and more rare here; the lynx, the wolf, and the bear, the latter attacking in preference the young calves, whose remains are often found in his stomach. Since the organization of game preserves by the Grand Duke Sergius, the number of wild beasts has considerably decreased and the protected game, the deer, the argali, the chamois, and the wild boar have proportionately increased. We have seen that the same is true of the bison during the past twenty years.

As regards the hunting of the bison, this is what we know concerning it: In 1848 an anonymous author published an account of a bison hunt in which were engaged the Abkhases (one of the numerous Caucasian tribes), in the basin of Zelentchouk, on the banks of the Ouroup and the Grand Laba, but this account was received with incredulity, and it was even conjectured that it was not the bison that was hunted, but another bovine animal, the gaur (*Bos gaurus*), an inhabitant of India, which was absolutely false, as is proved by the skins of bisons successively sent to the museums of Tiflis in 1864, 1869, and 1892. These three animals, killed by

inhabitants of the country, certainly came from the regions of Zelentchouk and the Grand Laba.

The first European hunter who had the fortune to meet and vanquish the living bison in the forests of the Caucasus was an Englishman, Mr. Littledale, a sportsman renowned for his hunting exploits in all parts of the world.

His first excursion, in 1887, begun too late in the autumn, was fraught with hardships, and, as the snow already covered the mountains, proved fruitless. The following year, accompanied by his wife, he spent three months on the heights. Having established his camp at an elevation of 6,000 feet he went out twice a week in search of bisons, guided by the native Tcherkesses. He often came across fresh traces of the animals, heard their trampling, saw trees that had been recently stripped of their bark, but in spite of twenty-four successive hunts he not only did not succeed in killing one, he did not even see a single one, so constantly watchful is this animal and so difficult to approach, scenting man at a great distance. This should be noted by those who deal with prehistoric times and seek to interpret the meaning of the representations of the bison which are found at Altamira.

Littledale returned to the charge, accompanied this time by a Lesghine by the name of Laubazon, famous for his experience as a poacher, and at the head of quite a squadron of mountain guides and skillful hunters. One fine morning in the month of August Mr. Littledale at length discovered a male bison and obtained a first shot at a distance of 90 meters; the shot took effect, but it was only at the fifth ball that the animal was killed, and fell into the river. Soon after Mr. Littledale killed a female. The skins of these two fine animals were presented to the British Museum. Some weeks after the hunter came across a male bison much larger and finer than the first two, but spared him, not wishing to be accused of contributing to the extinction of the race. The exploits of Mr. Littledale proved the possibility of bison hunts for the European, and were the occasion of measures being taken to protect the animal.

To-day the Grand Duke Sergius Michailowitch (with his guests) is the only one authorized to hunt the bison, but far from abusing his right he carefully guards the increase of the species. It may be said, too, that the first hunts of the Duke were equally unfruitful. In 1893 traces of the bison were found, and one bison was seen hidden in the high grass, but the hunters did not succeed in killing him. The following year the same Lesghine, Laubazon, started up two more without being able to reach them. Finally, in 1895, two superb bison were killed—a male by the Grand Duke and a female by Colonel Schilder of his suite. The skins were offered to the zoological museum of the Academy of Sciences at St. Petersburg. In the

BISON OF THE CAUCASUS, KILLED, IN 1895, BY THE GRAND DUKE SERGE MICHAILOWITCH.

year 1897 there were three more victims, two males and a female. One of the males killed by Doctor Reyer, director of the museum at Dresden, is to-day preserved in that institution. Since then the order as to the killing of the cows has been more strictly observed. The total number of animals killed does not exceed twelve.

I have already said that the bison of the Caucasus belongs, zoologically speaking, to the same race as those of Bielowitza, but it is distinguished by its height, which is relatively less, as well as by the conformation of certain parts of its body.[a] It is also much wilder and more difficult to approach than its kindred of Lithuania that have, for a long time, been accustomed to the presence of man and his domestic animals, by the side of which they are sometimes seen quietly feeding. In spite of the relatively small number of individuals, both at Bielowitza and in the Caucasus, no sign of degeneration of race has been manifested up to the present time. If the bison of Bielowitza, inhabiting a flat country, accessible in every direction, are quite easily captured, especially in the marshy portions of the forest, where they move about with difficulty, it is quite otherwise with the bison of the Caucasus. Up to the present time but a single living specimen has been obtained, and this, too, was but a young calf which had just been born. The story of its capture is interesting and worth recording here.

One of the wardens of the grand duke, hunting bears in the forest, perceived a bison cow hidden in the brush, with its little one at its side. At the approach of man the cow sprang up and was off like an arrow, abandoning its progeny to its sad fate. The little one also arose without any apprehension of danger, looked at the hunter with a stupefied gaze, settled back upon its haunches and at first did not

[a] Some Russian scientists think these peculiarities sufficient to mark the Caucasian bison as a variety which they designate by the name of *Bos bonasus caucasicus*, nov. subsp., but others do not agree with this opinion. We recall what confusion has reigned for a long time in the designations urus, aurochs, bison; in recent memoirs, M. Mahoudeau (Revue annuelle de l'École d'anthropologie de Paris, February, 1905), M. Lombard-Dumas (Bulletin de la Société d'études des sciences naturelles de Nîmes, in 1905, vol. XXXIII, November, 1906, pp. 37 and 65) and Prof. A. Mertens (Abhandl. des Museums der Magdeburg, 1906), contend that the aurochs is the *Urus* or *Bos primigenius*, which disappeared from Europe about the end of the sixteenth century, that it had neither hump nor mane, and that it, alone, left its remains in the caverns of Gard; since the time of Julius Caesar it has been continually confounded with the true bison (*Bonasus*), which has a mane, a hump, and smaller, less divergent horns; it is this and not the aurochs which was depicted at Altamira and in Dordogne. La Grande Encyclopédie (Vol. VII, p. 55) is therefore wrong in confounding the European bison with the aurochs. The whole matter is very much mixed. In order to fix the reader's ideas upon this subject we give (p. 347) a drawing of the skulls of four bovidæ—the Urus, the Bonasus, the buffalo, and the domestic ox.

try to get away. When its first astonishment had passed, it sprang up with a bound and began to scamper along the precipices. It would have escaped if its way had not been barred by a large uprooted fir tree. In trying to jump over this obstacle, as it had over others, it miscalculated and fell astride the branches. The man seized it by the hind foot.

In spite of its vigorous struggles he tied around its body his girdle and his baschlik (a sort of hood worn by the natives which has long lappets that are wrapped about the neck).

Curiously enough, after a moment's resistance, the animal followed his captor with docility. It, however, appeared to be out of breath, respired with difficulty, and the hunter feared lest it might die upon his hands. Coming to a keeper's house, he gave it some milk, which it at first refused, but two days afterwards it learned to lick the fingers of those who gave it milk, quite as do the young calves of domestic cattle when they are separated from their mothers. In ten days it was strong enough to continue the journey. It was tethered to a cart and led in this manner for some 10 kilometers, after which the hunters decided to unfasten it, and it followed the cart, running like a dog, for more than 60 kilometers farther. During the journey it was given milk to drink and consumed not less than 16 glasses of it per day.

Arriving at the village of Psébay, it was necessary to wait three months for the messenger for Bielowitza, who was charged with the duty of taking it to that place for breeding purposes. Kept in an inclosure covered with fruit trees, the young bison, which was still fed with warm milk, soon showed himself very fond of the fruits that he found in abundance on the ground, having a marked preference for the sourest kind of apples. Upon this diet the animal increased considerably in size and strength, so much so that he would knock over the cow that nursed him, attacking her in front in a playful manner. The messenger from Bielowitza found, however, that he was considerably inferior in size to the Lithuanian animals of the same age. This was perhaps due not only to the difference in race, but also to the lack of nourishment and to the long journey which he was forced to take but a few days after his birth.

The quantity of milk yielded by the female bison is not accurately known, but it is thought to be very abundant, for it has been shown at Bielowitza that a young bison raised upon the milk of a domestic cow consumes the milk of four cows. The poor Caucasian prisoner was far from having received as much as this during his early youth. He was affected by this all his life and remained a delicate, lean animal, of relatively small size.

During his journey from the Caucasus to Lithuania he was carried in a wagon, accompanied by a milch cow as a nurse and a provision

of 150 watermelons, which were sliced and fed him six times per day. He stood the journey well and arrived safe and sound at his destination.

He soon became accustomed to the usual winter provender of the bisons at Bielowitza, viz, clover hay, oats, and especially different kinds of roots, which he seemed to like very much. The following spring he was set at liberty in the midst of a herd of 15 bisons that adopted him as one of their own; he soon became as wild as the others, but never equaled them in size and always had a sickly appearance; his mane was scanty, his movements slow. He died the next year without leaving any progeny. So failed the first attempt at vivifying the strain of the bisons at Bielowitza by crossing them with animals originating in the Caucasus.

This capture of the young Caucasian bison proves, however, how readily the animal, in spite of its natural wildness, can be subdued and tamed. Experience has also often confirmed this fact and recently attempts have been made in Russia to cross the Lithuanian bisons with domestic cattle. We have good reason to count on the success of this experiment, as crossings between the American bison and domestic cattle have been attended with good results. Experiments of this kind have a very great interest.[a]

---

[a] In a paper published in 1906 (see footnote on p. 351) M. Mertens, director of the museum at Magdeburg, has collected all the known data concerning the wild cattle of Europe, citing the bibliography, giving a summary of the papers, and commenting on the results. He concludes that the name *aurochs* has been erroneously applied to the bison. In the middle of the sixteenth century the two species of animals were seen living together in the forests of Poland; in 1564 there was known to be in the forests of Jaktorowka a herd of 30 aurochs, which was reduced to 24 in 1599, to 4 in 1602, and to a single female in 1620. Some individuals lived in captivity up to 1627. The aurochs must have been black, or very dark, with a gray variety in Poland and a red one in Germany.

M. Mahoudeau (*loc. cit.*) adds that it is not always easy to differentiate the bones of the two species, but that no confusion is possble with the living animals.

THE FOUNDING OF COLONIES BY ATTA SEXDENS.[a]

By Dr. Jakob Huber (Para).

A study of the fungus-cultivating ants belonging to the genus *Atta* is undoubtedly one of the most attractive subjects of biology, and affords a number of highly interesting problems to both zoologists and botanists. From the time of Möller's classical investigations, proving the truth of Belt's theories, there has remained no further doubt that the species of this genus *Atta* maintain with marvelous understanding and skill pure cultures of fungus masses (*Rozites gongylophora*), and incite upon these, by influences not yet understood, the growth of the so-called "kohlrabi" structures, peculiar hyphæ swellings, with which they feed themselves and their young. Möller's investigations, known so widely as to need no special reference here, are concerned exclusively with definite ant colonies of numberless workers and in many apartments, but in respect to the founding of new colonies he has done no investigating.

The way in which a new colony, together with its fungus garden, is brought into existence has therefore remained to the present time a mystery, and although many valuable discussions upon the true solution of the problem have appeared they have failed to present a satisfactory answer to the difficulties. As early as 1894 A. G. Sampoïo de Azevedo, an observant Brazilian amateur, published some valuable observations on the founding of colonies of *Atta sexdens* in his rather untrustworthy brochure, Saúva ou Manhúuára (Sao Paulo, 1894). This investigator dug up a female *Atta* ten days after the mating period, and discovered in the underground compartment two small white mounds, one consisting of 50 to 60 eggs, the other of a filamentous mass—the young fungus garden—which, however, Sampoïo failed to recognize as such. Three and a half months after the nuptial flight he dug open a nest, the gallery of exit to which had been already opened. Within were numberless workers of three different sizes, all, however, somewhat smaller than those in established colonies. These were engaged in leaf cutting and in con-

[a] Translation, by permission, of Über die Koloniegründung bei Atta sexdens, von Dr. Jakob Huber (Para), in Biologisches Centralblatt, Bd. XXV, 1905, pp. 606–619, 624–635, Leipzig. Verlag von Georg Thieme.

structing a large fungus garden about 30 c. c. in size. Sampoïo estimated the number of workers to be between 150 and 170, with about 150 larvæ and nymphs and 50 eggs.

In 1898 H. von Ihering contributed some further facts on this subject.[a] He describes accurately the fertile queen ant burying herself in the ground. A day or two later he found this insect in its nest, but unchanged in condition, and several days afterwards he discovered a mound of from 20 to 30 eggs, near which was a flat mass of fungus of from 1 to 2 mm. breadth, without, however, any kohlrabi growing upon it. When the fungus bed had reached a diameter of 2 cm. the kohlrabi appeared, according to von Ihering, and one could often see the ants feeding on these. From eggs embedded in the fungus garden and lying on its surface larvæ had hatched out, but when the mass was removed the fungus wilted and the larvæ died. According to von Ihering's estimate, two to three months elapse from the start to the appearance of the first workers. He therefore concludes that the last portion of the breeding period must be one of some difficulty, seeing that as yet no leaves for the permanent growth of the fungus garden have been brought into the nest. But, as will be shown further on, the cultivation of the garden is provided for. According to my observations, herein recorded, it is by means of ruptured eggs that the proper organic substratum for the garden is supplied, the soil rich in humus also affording nourishment.

Von Ihering's most important statement is that in some alcoholic material he discovered the fact that each fertile female ant in entering the nest carries in a cavity at the back of the mouth a soft pellet about 0.6 mm. in size, consisting of filaments of the fungus, *Rozites gongylophora*, mixed with particles of bleached leaves and various chitin bristles. Unquestionably the possibility of a fungus garden being established by fertile females is rendered evident for the first time by this discovery.

In 1904 Professor Goeldi, by means of a brood case constructed for the purpose, watched the founding of a colony by a female *Atta* up to the time of the forming of the pupa; in fact, to the period of its "ripening" (metamorphosis), but he was disappointed owing to the death of the colony before the mature insects appeared. However, the possibility of a fully isolated female bringing into existence a colony was practically proven by this observation. In a communication on this subject to the Zoological Congress at Bern in 1904 Professor Goeldi draws the conclusion that on account of the peculiarly granular character of the temporary fungus garden it is probable that broken-up eggs are used as a substratum for the fungus.

---

[a] Die Anlage neuer Kolonien und Pilzgarten bei *Atta sexdens;* Zoolog. Anzeiger, Bd. XXI, pp. 238–245.

If we now group the results obtained from these previously mentioned investigations, we secure some such conception of what has already been done as that embodied in an article by Professor Forel, recently published in this journal.[a] It should be stated, however: (1) So far no investigator has succeeded in following the formation of an *Atta* colony up to the time of appearance of the young workers, much less the establishment of a permanent fungus garden. (2) The manuring of the fungus is thought by two authors to be accomplished by means of ruptured eggs; but this is not yet established beyond doubt. (3) Investigation has not yet revealed the source and method of feeding the larvæ.

On January 20 of the present year (1905), Professor Goeldi began a new series of observations of a number of females of *Atta sexdens* which had embedded themselves in earth inside of a breeding box of his construction. Although at the outset I was associated with him in these observations for the specific purpose of investigating the fungus, I was later on intrusted with the entire investigation, Professor Goeldi being absorbed in other work. During my studies and observations, continued in an unbroken series through February, March, and April, I repeatedly received aid and encouragement from Professor Goeldi, especially in matters of information relating to literature bearing on this subject. In recognition of this I desire to here express to him my heartiest thanks.

The series of observations, begun January 20 with about 12 fertile females, were further enlarged by two other series containing numberless individuals, secured from flights occurring on February 23 and March 12, a circumstance that rendered possible investigations by diverse methods of cultivation. On this point it is sufficient to here state that besides a large number of cultures in the Goeldi breeding case filled with earth, others were placed in crystallizing dishes (to afford observation from above) and in small plaster boxes having glass sides at front and back (to afford observation from the side); and in addition to these a number of nests in the open ground, marked at the time the fertile female embedded herself, were opened at the proper time as indicated by a control experiment. These observations were so far crowned with success as to result not only in following, without a break, several cases of the founding of new colonies from the beginning to the time of appearance of the workers, but also in some instances in observing the commencement of leaf-cutting operations and the constructions of a permanent fungus garden. Repeated and careful observations of the *Atta* female and her descendants yielded also a number of interesting facts which I shall here merely enumerate, reserving for a more elaborately illustrated

[a] Biolog. Centralblatt, Bd. XXV, p. 170 ff.

treatise the specific facts of the studies, the full details of the separate lines of observation, and the specific mycological results obtained.

The initial steps in founding a colony are most readily observed by inclosing the female *Atta* in a glass-sided compartment kept sufficiently humid by means of dampened blotting paper. On the day following the nuptial flight the ant is seen to have disgorged the small pellet of fungus threads upon the ground, where it may be easily overlooked, being hardly more than 0.5 mm. in diameter, frequently yellowish or almost black instead of white, and therefore lost sight of among the other materials. I have found that as a rule a few eggs (6 to 10) are to be seen after the third day, and the fungus pellet is found to be sending out delicate threads (hyphæ) in all directions. (Fig. 7.) On the same or the next day the ant separates the fungus into two or three small heaps. (Fig. 8.) During the next ten to twelve days there is usually a daily increase of about 10 eggs, though this varies in individual cases. At the same time the fungus patches increase in number and size. They have a diameter of 1 to 2 mm. and closely resemble small cotton seeds covered with erect threads. At first the eggs and fungus masses are separate, but after a time they are brought together, or, at any rate, part of the eggs are placed upon and between the fungus patches. At the expiration of eight to ten days these patches are so numerous that they unite to form a round or elliptical shield-shaped growth with a diameter of 1 cm.; and from this time on the eggs are to be found on this growth. In time it becomes so compacted that with a little care the entire platter-shaped mass, together with the eggs upon it, may be raised from the ground, the outer rim being usually quite thick.

Somewhere about fourteen to sixteen days after the female *Atta* has established her subterranean dwelling, the first larvæ can be clearly seen lying among the eggs which by this time amount to over 100. The fungus garden is now from 1 to 1.5 cm. in diameter. The number of larvæ increases daily and their rapid growth is especially striking, some attaining within a week a length of fully 2 mm. A month or so after the beginning of the imprisonment the first pupæ are to be seen. They vary in size, the smaller being 1.5 to 2 mm., the larger 2.5 to 3 mm., or, in rare cases, 4 mm. At this time the fungus garden has attained a diameter of about 2 cm. and has a perceptibly thickened rim. During its early development there is no trace of kohlrabi formation observable (cf. figs. 7–11 and 6). Now, however, these bodies can be indistinctly seen on the border of the fungus garden. Eight days later, when there are about 30 pupæ, the older of these begin to take on a brown color, and a few days after this the first young workers appear. They at once busy themselves with the care of the pupæ and the person of the queen, and begin feeding on the kohlrabi.

It is necessary to state here that the foregoing case of development in forty days is the most successful one that I have in my record of cultures. However, the majority of cases belonging to the last flight of female ants, which occurred on March 12, are classed to this category. Some few of these were, together with their offspring, very slow in development, and some of the broods required a period of two months and three days before the first working ant appeared and became active.

These, in a general way, are the facts observed in a preliminary study of the founding of a new colony by *Atta sexdens*. But there are a number of questions, answers to which are imperative for the biologist, and the solving of which becomes possible only by very critical observation. These problems are the fertilizing of the fungus garden and the nourishment of the mother ant and her young brood.

The question of chief moment is this: What means are employed by the queen ant to stimulate and maintain the growth of the fungus brought by her in the cavity at the back of the mouth? For this organic source of supply needs to be developed in the shortest possible time, and it is evidently out of the question to suppose that a pellet of fungus hardly 0.5 mm. in diameter can be made to grow into a fungus garden of more than 2 cm. in diameter and bear its fruitage of kohlrabi without some special means of nourishing. A microscopical examination of a young fungus garden reveals a meager substratum of plant material recognizable as fragments of plant epidermis, vascular tubes, corroded starch grains, and crystals of oxalate of lime. But these substances are to be found in like proportion in the original fungus pellet, and it is evident they were transported with it from the mother colony. In addition to these materials there are soon seen to be among the fungus masses torn fragments placed here and there and saturated with a yellowish liquid, and even without the aid of a lens yellow areas and yellow or brown drops are discoverable. These drops are the key to the puzzle as to the mode of nourishing the young fungus garden.[a] There is no doubt as to the fact of this manuring of the fungus by the ant with liquid excreta. The further cultivation of the garden consists in licking the threads (hyphae), a process that hardly tends to promote growth, but rather serves to control and guide it in certain directions. The operation is also an agreeable one for the ant, as certain transparent drops are exuded from the fungus which she consumes. The development of the new fungus garden is therefore seen to be essentially a matter of its enrichment by means of excreta, and the granular or flecked appearance of the fungus, as well as the constant increase in the num-

---

[a] The author at this point enters into a detailed and unreserved description of manuring the fungus beds by the female *Atta* by the use of excreta of her own body. A literal translation of this passage is here omitted.—Translator.

ber of the patches, are clearly explainable by this process of manuring. The occasional use of crushed eggs as a manure has never been detected by me in any microscopic examination of the fungus garden nor seen by direct observation, although in an indirect sense it is evident that the eggs may be looked upon as a source of enrichment. According to my observations the manuring of the fungus begins very shortly after the flight from the mother colony, and it continues until the establishment of the garden is completed.

If an active *Atta* female is watched for several successive hours it is seen that her work is methodically arranged. The inspection of the apartments and the cleansing and leveling of the floor require comparatively little time after the initial work is done, but are nevertheless attended to at stated intervals. Then comes the care of the fungus gardens, a task requiring more time, followed by a third and supremely important duty, the care of the young brood. Eggs and larvæ require to be diligently licked, placed in clusters, or spread out separately, put in contact with the fungus or separated from it, and later on laid in the hollow center of the fungus garden, or certain individuals of the brood removed from it. By the use of a plaster box or a Goeldi nesting case, egg laying and the process of manuring can both be readily observed by means of a hand lens, or photographs can be taken (see figs. 18 and 19). The ant raises itself upon the middle and hind limbs and receives the egg in its mandibles. After a lengthy examination with its feelers the egg is placed with the others in the center of the fungus garden. This procedure is not always followed. By very careful observation, and especially when the ant can be watched in profile, so that the motions of the mouth parts are plainly observable, it is possible to discover that the egg, after being carefully tasted, is not actually deposited, but taken up again, tasted anew, and then suddenly disappears in the mouth. The mandibles are not, however, brought into action, but the ant remains for some seconds perfectly motionless, the head held above the fungus garden, the feelers moving lightly, indicating a state of satisfaction. The mandibles and tongue now move rapidly, and the front feet are drawn through the mouth parts in a peculiar way. It is evident that this period of poise and activity indicates that the ant is devouring or sucking the contents of the egg, which is pressed between its mouth parts. Usually it is not immediately eaten, but quite a period of tasting and an apparent state of indecision on the part of the ant seems to take place. Much more infrequently those eggs are eaten which have been actually deposited—at least this is the case under normal circumstances, when, for example, the fungus garden is already developed. If, however, this source of supply is lacking, the before-mentioned occurrence is more common, and a gradual decrease in the number of eggs already deposited can then be

easily seen. It may be said that the devouring of eggs is a very common occurrence. I have seen it take place as often as six times in two hours—in fact, as often as four times in a single hour—and have noticed it in the case of all the *Atta* females that have been under my observations. According to my investigations, it may be stated that during the early breeding period an *Atta* female will, on the average, lay not less than 2 eggs every hour—that is, approximately 50 eggs a day. But as has already been stated, during the first ten or twelve days the number of eggs increases only about 10 daily, so that for each 5 eggs laid 4 must be eaten. If the total of the eggs for the period of brood development is estimated up to the time of the appearance of the first working ants—let us say a minimum of forty days—we get a total of 2,000 eggs, whereas the entire brood at this time, including unhatched eggs, larvæ, and nymphs, will not exceed 200. We therefore find a proportion of 9 eggs devoured to every 10 laid.

The foregoing especially unfavorable proportion is doubtless to be attributed to the fact that the larvæ required from the beginning to be fed with the eggs. The feeding of larvæ is a process somewhat more difficult to observe than that of manuring the fungus-garden, the egg laying, or the devouring of the eggs on the part of the female, because it only rarely happens that the larvæ are in a position to be accurately observed; but on several occasions I have been fortunate enough to have this procedure, from beginning to end, under inspection by means of a hand lens. When the egg has been laid, the mother-ant tests it for some seconds by a process of tasting, and then turns to one of the larvæ, which she caresses with her antennæ until it begins to move its mandibles. The egg is then thrust between its mouth parts with considerable force. These continue to work back and forth upon the egg, which either stands perpendicular to the larva, or, as is more frequent, lies along its ventral side. In the latter case the mother-ant often presses the egg with her foot against the larva. If it is still very young, the egg is generally after a time taken away and given to another larva. A good-sized larva is, however, capable of devouring an egg in from three to five minutes, so that nothing but the leathery skin remains, which is later removed by the mother-ant. At any rate, I have clearly observed that a larva whose mouth parts were in vigorous action upon an empty egg-skin had this residue licked away by the mother-insect, and that then the movements of the larva ceased. It is no doubt due to the rapidity with which the larvæ devour the eggs that one so very rarely comes upon them in the actual process of eating them, but I have clearly established the fact that feeding of larvæ with eggs is a very frequent occurrence. Thus, for example, I have noted in a forenoon the process of egg laying to take place four times and

the feeding of larvæ with eggs an equal number, and in an afternoon during two hours eight cases of egg laying and four of feeding these to larvæ. I am of the opinion that up to the time of the appearance of the workers eggs form the exclusive food of both the mother-ant and her brood. I have never detected a case of the *Atta* female supplying the larvæ with either the mycelial threads or the kohlrabi of the fungus (*Rosites*). Furthermore, in opposition to Von Ihering's observations, I have never seen the mother-ant herself feeding upon the kohlrabi. These structures appear on the fungus-garden after about a month, but I have been impressed with the indifference toward them uniformly displayed by the *Atta* female. In order to test this, I have several times supplied a mother-ant which had lost her supply of fungus with a portion thickly beset with kohlrabi formations. This she has applied to the purpose of cultivation without showing any interest in the kohlrabi. The latter remained untouched for a week or more and were finally hidden under a growth of mycelial threads. The most conclusive proof that the fungus plays no appreciable part as a food supply during the earlier portion of the breeding period and up to the time of the appearance of the workers is the fact that the female *Atta* is able to raise her brood in the absence of this fungus, although in diminished numbers. I have, indeed, never seen such an occurrence under natural conditions and only once under the artificial culture conditions. A migrating female which left the nest on the 12th of March had on the 17th of March been unable to secure any mycelial growth with her transported fungus pellet, which remained blackish in color. On the 18th of March the female secured from another ant a piece of fungus from a fungus-garden. It was immediately cultivated, began to grow, but early in April proved a failure. From that time on the work was carried on without any fungus. The number of larvæ and pupæ were fewer than in other colonies of equal age, but on the 25th of April there were two workers of average size, and on April 30 seven vigorous workers. The devouring of eggs by isolated female ants is made evident in an indirect way by the disappearance of eggs already laid, although the process has never been observed by me. In regard to the feeding of the brood by a solitary maternal ant, Janet and Forel, as I understand it, have advanced the opinion that the larvæ are fed with a nutritive liquid derived from eggs devoured by her and which she secretes in the communal stomach (jobot). In respect to *Atta*, at least, this is not the case. The eggs are here directly fed to the larvæ. Comparative investigations must determine whether or not this method of feeding takes place with other ants. It is at least noteworthy that in the case of *Atta* the larvæ are not later on fed by the workers with their

stomach contents, but directly with the kohlrabi growth of the fungus.

A new period of existence for the colony begins with the appearance of the first workers. On the one hand, new necessities arise, as the young workers bring a decidedly good appetite along with them. On the other hand, no inconsiderable help is afforded to the mother ant in the care of the fungus garden and the brood, these workers displaying from the first moment of their existence a purpose to be true to their name. The manifold intelligence and dexterity of the *Atta* female is by no means dispensed with at once, particularly as the workers hatch out gradually. After the appearance of the first set of workers, which almost uniformly are of a very small variety, measuring only 2 mm. in length, their number increases daily by from 3 to 4. Soon after this (in rare cases on the very first day) there appears another variety with a body length of 3 mm. The duty of cleansing, smoothing, and putting into physical condition these first workers falls naturally upon the queen. But after these have come upon the field of action they take up the future care of the metamorphosed pupæ up to the time of their coming out into the adult state, whereas the queen shares in these activities quite infrequently. The care of the fungus-garden is from this time on attended to mutually by the mother and the workers. The former continues to manure the garden in the usual manner. The young workers also share in this work, depositing the excreta in the form of minute yellowish drops. It is droll to note with what scrupulous care they select the desired places for this enriching, and how the mother ant approaches and displays an interest in the operation, inspecting the places and assisting to prepare them. In addition, the young workers take up the task of transporting little masses of the fungus mycelium to the freshly manured areas, so that the elevated border of the garden appears built up here and there with minute mounds. On account of this united activity on the part of queen and workers in enriching the fungus-garden, its dimensions increase considerably, rarely, however, going beyond 2.5 cm. before the process of leaf cutting begins. The larvæ, the number of which rapidly increases, are still fed with eggs. It is of interest to observe how in this task the workers gradually relieve the mother-ant of the larger share. It often happens that the mother-ant places an egg in the regular way against the mandibles of the larva, but it is frequently seen that it is not satisfactorily arranged or is simply deposited in the nest; in the latter case the workers pick it up and give it to the larva. The workers also stroke the larvæ with their antennæ in the same manner as the mother-ant, so as to cause them to move their mandibles when the egg is given to them. I have

generally been able to observe the same egg being given to several larvæ by the workers, who slowly squeeze it with their mouth parts. The food of the workers at this period consists of kohlrabi. This has been developed for some time and is seen in large quantities along the margin of the fungus-garden. As a rule the little workers are incapable of consuming an entire kohlrabi, but merely nibble upon it where it grows, licking up the crystal clear drops that ooze out of its interior. Often, however, these bodies are cut from the fungus and then devoured by two or three workers or are passed on from one to another of them. It is not at all improbable that in feeding the larvæ the workers themselves occasionally consume some of the liquid contents of the eggs. Once at least I detected a worker trying to squeeze out the contents of an egg between the mandibles and maxillæ; she was, however, prevented by another worker. In regard to the nourishment of the queen, I am compelled to admit that I am somewhat in the dark, for after the appearance of the young workers I have observed only a solitary case, and that a rather doubtful one, of the queen devouring an egg. Whenever I have seen an egg laid I have noticed that it was either deposited in the nest or given to the larvæ. The queen does not feed upon kohlrabi at this period any more than previously. I have, however, observed the process of a worker approaching the queen, spreading its mandibles and offering its tongue, which is then licked by the queen. At first I believed this to be a case of the feeding of workers by the queen, but inasmuch as the workers feed upon kohlrabi such a conclusion is rather improbable, and the more plausible explanation seems to be that the worker is in this way offering some nourishing liquid to the queen. On this point further investigation is needed for a safe conclusion.

The workers, which, as previously remarked, are of two sizes at the beginning, do not display any definite distinction in their labors. On certain days they are to be seen almost entirely concerned with the fungus garden, only rarely one or another of these moving a few steps away. At the expiration of a week I first noticed a solitary worker making excavations in the earth, without my being at all certain that it was in any way connected with the preparation of an exit tunnel. About the same time there began to appear workers with massive heads 4 to 5 mm. long. In one of my cultures, nine days after the appearance of the first workers, and when there were about 35 of these, I noticed for the first time the young workers very busy in mining operations, two tunnels on opposite sides about 2 mm. wide being excavated, and even the smallest of the workers sharing in the operation. In the case of another colony of mine I discovered on the 2d of May, ten days after the appearance of the

first worker, the commencement of an exit tunnel, the mouth of which was soon surrounded with a quite high crater. (Fig. 25.) With still another colony, founded like the former one on March 12, the same conditions were noted May 5. In both of these cases pieces were cut from rose leaves that had been supplied and were carried down into the nest.

Here we pass from the transitional period into the definite period of the construction of the fungus garden. I had not, up to this time, actually seen any cases of exit tunnels under natural conditions; the before-mentioned experiments making it evident that seven weeks after the founding of the colony its young workers are in condition to open up connection with the outer world and to take up the task of leaf cutting.

For the purpose of accurately studying the definite period of fungus garden construction, a queen ant and thirty young workers, together with a transitional fungus garden, were placed in a glass case without any soil, and a rose leaf was then introduced. The date was April 30. Three hours after this I found the leaf cut up and the minute, irregular fragments worked together into small masses and placed at various points around the border of the fungus garden. During the afternoon of the same day scraps of the fungus mycelium selected from other places, particularly from the underside of the fungus garden, were planted on these leaf fragments. During succeeding days, the circumference of the garden was visibly raised by means of repeated additions of new leaf fragments, and particles of mycelium planted upon them, so that the young brood came to be, after a while, in a sort of room, which later (May 4) had been almost completely roofed over. Alongside of this the first foundations of adjoining apartments were constructed, one of which served the purpose of a storeroom for the more or less completely chopped up and interwoven leaf particles. During the process of leaf cutting, performed, as would be expected, only by the larger individuals, and the building up of the definite fungus garden, in which the smallest workers share, the process of manuring seems to be no longer carried on—at least I have not been able to observe it. The queen appears to look with very little favor upon this new method of fungus culture. Often standing immovable, and as if sulking, she turns sideways to the garden and goes to it only for the purpose of inspecting the work, hastily licking the fungus, laying her eggs, or feeding the larvæ with them, and even in these matters the workers frequently replace her, snatching the eggs from her mandibles and even taking them from the abdomen. There now sets in for the queen a period of gradual retrogression, which terminates finally in debasing this painstaking and industrious mother into a mere egg-laying machine. The domi-

nant factor in this gradual retrogression is mainly the overabundance of workers, the activities of which perpetually hamper the queen. It is partly due also to the rapid development of the fungus garden which precludes the possibility of its care and inspection being accomplished by the mother ant. Apparently, also, the new mode of fungus culture is uncongenial to the queen, and as a consequence she gives up her own share in this work. The care of the metamorphosed pupæ is, as we have already seen, the first responsibility that the queen relinquishes into the hands of the workers. In the matter of tending the larvæ during the transitional period, the duty is narrowed down to simply supplying them with eggs, and this, as already noted, is more and more delegated to the workers. In consequence of this steady enlargement of the fungus garden the larvæ (and the eggs as well) are gradually removed from the domain of the mother ant. It is not surprising that at first the larvæ continue to be fed with eggs, since at this period the quantity of kohlrabi is small, being barely sufficient for the adult workers. Nevertheless, I once noticed a small worker offering a half-eaten kohlrabi to a larva, and finally mashing it up in a very practical way in front of its mouth. In this way a beginning is doubtless made in the further feeding of the larvæ with kohlrabi, which comes to be a general thing as soon as the necessary supply is obtainable. The time at which the feeding of the queen with kohlrabi begins is at present undertermined, a process seen by Professor Goeldi and repeatedly by me as well, in the case of old colonies. In all probability the workers adopt this source of supply as soon as kohlrabi is plentiful enough. If my theory regarding the feeding of the queen by the workers during the transitional period proves to be the correct one, this period would then be the natural time of changing from the original egg diet to a vegetable diet upon kohlrabi.

Although it becomes evident from what has been previously here recorded, that in the case of *Atta sexdens* the foundation of a new colony is possible by means of an isolated fertile female and often doubtless takes place in nature, this does not in any sense exclude the possibility of such a colony being founded by adoption. A number of my investigations bearing on this point have been fully successful. For example, fig. 26 represents a colony resulting by adoption of a queen on the part of workers from an old nest. The fertile female, held in captivity for a month, and taken during the breeding period, was carried away by the workers to a subterranean nest. At first she sought to share in the care of the fungus garden and the young brood, but was prevented from doing so to any considerable extent by the swarm of workers, and at length seemed more and more to sink

into a condition of brooding, and abandoned at last even the attention to her own eggs.

Summary.—The most important points of the foregoing investigations may be summarized as follows:

First. The fertile female of *Atta sexdens* has the capacity, without any outside aid or supply of nourishment, to found a colony in an underground cavity excavated by herself.

Second. The length of time for the development of this colony up to the first appearance of the workers, comprises, under favorable circumstances, in the vicinity of Para, a period of forty days. The first larvæ appear after fourteen days, the first pupæ at the end of a month. After the arrival of the first workers at least a week elapses, and in nature perhaps a longer period (transitional period) before any communication with the outer world is made and the work of leaf cutting begins.

Third. The fungus is at the outset manured with excreta from the mother ant, and during the transitional period from the young workers also.

Fourth. The mother ant is at first nourished with her own eggs, only an inconsiderable percentage of which are reserved for the process of hatching. Furthermore, although she licks the growing fungus, she never feeds upon it. After the first workers make their appearance the mother ant is probably fed with the fungus.

Fifth. The larvæ are at first fed with eggs by the mother ant, and during the transitional period by the young workers.

Sixth. The young workers from the very start feed upon kohlrabi.

PARA, *May 4, 1905.*

PLATE I.

FIG. 1.—Entrance opening to subterranean nest of female ant. Pellets of earth arranged about the opening. ½ nat. size.

FIG. 2.—Vertical section through subterranean nest, after 11 days. Nat. size.

FIG. 3.—Nest in a Goeldi breeding case; 16 days old. Nat. size.

FIG. 4.—Sagittal section through head of Atta female, soon after leaving parental nest; mouth closed; fungus pellet in its special cavity. Magnified about 9 times; somewhat diagrammatic.

FIG. 5.—Same as fig. 4; mouth parts extended to show mechanism for expelling fungus pellet.

FIG. 6.—Mycelium of temporary fungus garden. Magnified about 150 times.

FIG. 7.—Eggs and fungus patch 2 days after the nuptial flight. Magnified 5 times.

FIG. 8.—Same, 3 days after nuptial flight. Magnified 5 times.

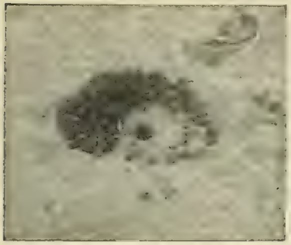


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

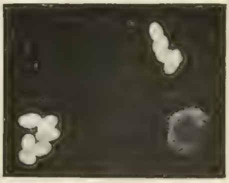


Fig. 7.

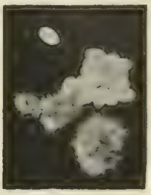


Fig. 8.

FOUNDING OF COLONIES BY ATTA SEXDENS.


Fig. 9.

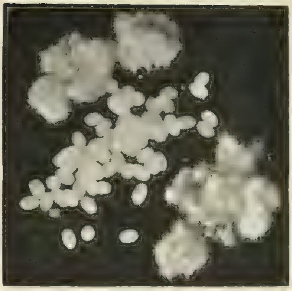


Fig. 10.

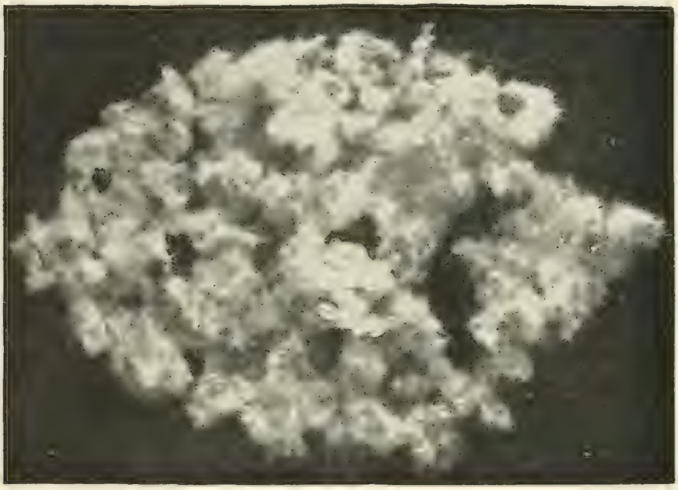


Fig. 11.


Fig. 12.

FOUNDING OF COLONIES BY ATTA SEXDENS.

PLATE II.

FIG. 9.—Same, 7 days after nuptial flight. Magnified 5 times.

FIG. 10.—Fungus garden 10 days old; *d*, excreta drop. Magnified 6 times.

FIG. 11.—Fungus garden 14 days old, with about 100 eggs and numerous excreta drops. Magnified 5 times.

FIG. 12.—Fungus garden 4 weeks old, with numerous larvæ and several pupæ. Magnified 5 times.

PLATE III.

Fig. 13.—Manuring the fungus garden. Instantaneous photograph taken in a plaster breeding case after the method of Janet, adapted for use with *Atta* by Goeldi and Huber. Nat. size.

Fig. 14.—Same. Nat. size.

Fig. 15.—The mother ant at her toilet. Nat. size.

Fig. 16.—Kohlrabi growths; the fungus threads have been somewhat separated. Magnified 150 times.

Fig. 17.—Process of licking fungus garden by the mother ant. Instantaneous photograph in the Goeldi breeding case. Nat. size.

Fig. 18.—Egg laying. Nat. size.

Fig. 19.—The same. Nat. size.


Fig. 13.


Fig. 14.


Fig. 15.


Fig. 17.


Fig. 16.


Fig. 18.


Fig. 19.

FOUNDING OF COLONIES BY ATTA SEXDENS.

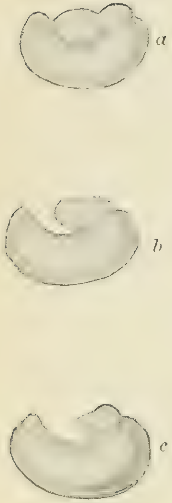


Fig. 20.

Fig. 21.

Fig. 22.

FOUNDING OF COLONIES BY ATTA SEXDENS.

PLATE IV.

Fig. 20.—Feeding a larva. *a*, *b*, *c*, successive stages of the process. Reduced drawing from a micro-photograph. Magnified about 10 times.

Fig. 21.—Mother ant upon the nest, at the time of appearance of the first workers.

Fig. 22. Fungus garden after the appearance of the first workers. Along the border drops of excreta the mother ant and several small workers can be seen. Magnified 3 times.

PLATE V.

FIGS. 23, 24.—Fungus garden and queen 3 days after the beginning of the leaf-cutting process. Worker feeding (?) the queen. Nat. size.

FIG. 25. Exit opening of a young colony, (*a*) a sheet of glass (*g*) placed over the nest. Rose leaves, from which pieces have been cut, lying near the opening; one piece left by the ants on the rim of the crater. Slightly reduced in size.

FIG. 26.—A young adopted colony of *Atta sexdens*. The white spots represent the mass of kohlrabi formations already developed in the fungus garden. Queen dimly visible at (*k*).

Fig. 23.

Fig. 24.

Fig. 25.

Fig. 26.

FOUNDING OF COLONIES BY ATTA SEXDENS.

QUATERNARY HUMAN REMAINS IN CENTRAL EUROPE.

By Hugues Obermaier.[a]

INTRODUCTION.

In order that the great problem of quaternary races in central Europe may be presented with accuracy and reliable conclusions be reached, it is indispensable to begin by establishing a list of well-authenticated quaternary anthropological discoveries, and separate from it all finds the age of which is not settled. A record of this nature can be accomplished only by patient and methodic discrimination based on a painstaking study of the localities, the objects recovered, and the publications relating to ancient man. With the aim of producing such a record, the writer has applied himself for several years to the study of everything that appeared in print on the subject of quaternary man in Europe, and visited, as far as possible, the collections, the localities of the finds, and the men who made the discoveries. The present publication is the result of these researches; it is purely geological and archeological in nature, nevertheless the data will also be of service to those who may desire to deal with the problem from the standpoint of physical anthropology or comparative anatomy.[b]

GEOLOGICAL CHRONOLOGY OF THE QUATERNARY PERIOD.

For accurate chronology of the quaternary of the Alps we are indebted to A. Penck and E. Brückner. This chronology was briefly outlined by the writer himself in L'Anthropologie and extended to the rest of Europe in another publication, and geologists dealing with northern Germany and England conformed to it in all essentials. M. J. Partsch has shown that glacial phenomena presented the same characteristics over all the other mountainous masses of Europe, and that what can be termed the climatological harmony of Europe has been everywhere lowered by several octaves during

[a] Abstract, translated by permission, from L'Anthropologie, T. XVI, Nos. 4–5, 1905, and ibid., T. XVII, Nos. 1–2, 1906, supplemented with author's additions.

[b] For detailed bibliographical references the reader is referred to the original papers in L'Anthropologie.

the glacial periods. Due to this, every one of the ice invasions in Middle and Western Europe manifested, even in regions where it left no geological traces, a distinct arctic-alpine fauna.

Penck endeavored to apply his geological chronology also to the known sites of quaternary man, but he encountered difficulties on account of finding only the so-called Magdalenian stations in direct connection with the glacial deposits. This circumstance made it possible to eventually determine the late postglacial age of these particular remains. The more ancient stations of the Solutrean mammoth hunters lie in the loess, far from the Alpine ice centers and without a direct connection with these, and the determination of their exact antiquity presents more obstacles. However, on the base of the information then extant, Penck constructed the following chronological scheme:

I. Glacial period.
- 1. Interglacial period.

II. Glacial period.
- 2. Interglacial period: Chelléen culture.

III. Glacial period: Mousterian culture (cold climate).
- 3. Interglacial period.
  - (*a*) Warm—Mousterian culture (end).
  - (*b*) Cool—Solutrean culture.

IV. Glacial period.
- Postglacial time—Magdalenian culture.

It was the above chronology which I have utilized in my writings (including the French version of this paper). Since the publications in L'Anthropologie, however, my geological and archeological investigations in Villefranche and the Pyrenees resulted in new evidence, on the basis of which I must modify the above scheme as follows:

I. Glacial period.
- 1. Interglacial period.

II. Glacial period.
- 2. Interglacial period.

III. Glacial period.
- 3. Interglacial period.
  - (*a*) Warm—Chelléen culture.
  - (*b*) Cool—Achelléen culture.

IV. Glacial period: Mousterian culture.
- Postglacial time.
  - (*a*) Solutrean culture.
  - (*b*) Magdalenian culture.

This new and more satisfactory chronology relating to the geologically ancient man of central Europe is sustained also for the Alps by the recent discovery of a paleolithic station at Santis (Canton St. Gallen). The "Wildkirchli" cave in this locality, at 1,500 meters above the sea, shows intact Mousterian industry. This deposit could have taken place only after the recession of the glaciers of the fourth (last) ice invasion.

PART FIRST.—DISCOVERIES IN AUSTRIA-HUNGARY.

The first part of this report will be devoted to the ancient osteological discoveries made in Austria-Hungary. The quaternary archeological deposits of this country are divided into two large groups, namely, those which occur in the loess that covers a great portion of the surface of the Empire, and those which are found in caves. The latter are again divided into two classes, one, the more ancient, belonging to the lower layers of the cavern deposits and characterized by only the lower-paleolithic implements of a very primitive nature—the other distinguished by the presence of flint implements of definite and much varied forms as well as by bone implements, and belonging to the more recent Magdalenian culture. The industry represented in the loess finds is typically Solutrean and belongs chronologically between the two of the caves. This fact has been established by stratigraphic observations, particularly in western Europe, and is supported by the clear separation between the objects of the cave and the loess finds, even where such deposits existed in immediate vicinity.

The old-paleolithic stations of Austria-Hungary show especially implements of atypical forms, with which are mixed comparatively few Mousterian varieties.

According to the writer's new chronological table the sites of quaternary man in Austria-Hungary, which have yielded with other objects remains of the human skeleton, range as follows:

III. Glacial period.
- 3. Interglacial period.
  - (*a*) Warm—Krapina (Croatia).
  - (*b*) Cool—Šipka (Moravia); possibly also somewhat later.

IV. Glacial period.
- Postglacial time.
  - (*a*) Last loess phase (Solutrean)—Willendorf (Lower Austria) Predmost; Brno (Brünn) (Moravia).
  - (*b*) Magdalenian culture—Gudenushoehle (Lower Austria).
    Louč (Lautsch), Lichenstein cave (Moravia).

I.—*Human remains, surely quaternary.*

Archeological remains of the quaternary man are frequent, those of skeletal nature are rare. I shall give the discoveries belonging to this category of the finds in their chronological order.

THE CAVE OF ŠIPKA.[a]

In northern Moravia, 10 kilometers east of Nový Jičín, is the jurassic mountain Kotouč. This mountain, which is visible from afar

[a] Ch. Maška: Mittheilungen d. Anthrop. Gesellsch. in Wein, 1882, p. 67. Also: Der diluviale Mensch in Mähren. Nový Jičín (Neutitschein), 1886, p. 67 (with one figure of the jaw).

and presents a flat summit and steep precipices, contains numerous caves, the most spacious of which on the north is called Šipka. Up to the time of the explorations of Karel Maška this cave consisted of a simple room 9 meters long, 6 to 12 meters broad, and 1.50 to 2.50 meters high, the rear being completely filled with large pieces of calcareous débris. The researches of Maška show that this débris was the result of caving in of parts of the roof dating from the end of the quaternary period, and that behind the mass of fallen rock the cavern ran 55 meters more into the mountain. The following account of this station is based on the publications of Maška and personal information in the autumn of 1902:

Šipka is divided into three parts—an anterior portion already mentioned; a middle portion, 9 to 12 meters broad and 10 meters long, filled up to Maška's excavations with pieces of the fallen roof, and a posterior portion behind the great pieces of rock, about 30 meters long and ending in a narrow fissure, which prevents farther advance. In the left side of this last portion is a narrow and low lateral chamber, known as the "badger-hole," which runs 15 meters and opens on the outside of the mountain. Explorations in this compartment have shown that it also was closed before the end of the quaternary.

The deposits found in the cave and their stratigraphic relations were as follows:

Cave Šipka.

Anterior part.	Middle part.	Posterior part.	Badger hole.
(*a*) Modern deposits.	Caved-in rock.		
(*b*) Cave loam (yellowish brown). Archeological remains scarce.	Same as (*b*).	Cave loam. Archeological remains (superior paleolithic).	
(*c1*) Gray layer, with archeological remains. (inferior paleolithic).	Same as (*c1*).	Same as (*c1*).	
(*c2*) Gray layer, without traces of man.	Same as (*c2*).	Same as (*c2*); deposit more greenish.	
(*d*) Greenish layer. The principal repository of archeological specimens.	Same as (*d*).	Same as (*d*); layer more brownish.	Archeolgical deposit (inferior paleolithic).
(*e*) Gray and greenish sand.	Same as (*e*).	Sand and rubbish.	Sand and rubbish.

As high up as layer (*b*) the quaternary fauna was intact, showing no mixture with the modern. Layer (*b*) showed, in the anterior portion of the cave, remnants of *Rangifer tarandus*, *Elephas primigenius*, and *Rhinoceros tichorhinus*, with two fireplaces and some flint chips. In the middle compartment this layer yielded bones of

Myodes torquatus, *Lagopus albus* and *alpinus*, *Lagomys pusillus*, and *Spermophilus rufescens*. The same arctic-alpine fauna was associated in the posterior chamber with a well-marked archeological deposit showing several fireplaces and yielding flint implements of the superior paleolithic type. Layer (*c1*) inclosed the *Elephas primigenius*, *Rhinoceros tichorhinus*, and a predominance of *Equus caballus*, whereas *Rangifer tarandus* was missing. Archeological specimens were numerous, especially in the inferior parts of this layer, and consisted of crude, atypical implements, made mostly from quartzite. Layer (*c2*) consisted in its superior portion of a mass containing numerous remnants of carnivores; it was 0.5 meter in thickness and showed no traces of the presence of man. Layer (*d*), inclosing the principal archeological deposit, contained also arctic-alpine fauna, including *Gulo borealis*, *Myodes torquatus*, *Rangifer tarandus*, *Capella rupicapra*, *Capra* (*Ibex?*), *Arctomys* sp., *Rhinoceros tichorhinus*, *Elephas primigenius*, *Ursus spelaeus*, *Bos primigenius*, *Equus caballus*. The implements, about 3,000 in number, are with few exceptions only formless, rudimentary, quartzite spalls; they were disseminated through and about the fireplaces and were mixed with calcined bones.

A piece of human lower jaw was discovered at the side of a fireplace situated at the point where the middle portion of the cave ends and the *badger hole* commences. The fragment was in layer (*d*), at the depth of 1.40 meters, near the lateral wall, and lay in ashes. The middle portion of the bone is alone preserved; it contains three incisors, the two right bicuspids, and one right molar. The incisors are worn off to the cement. The bone shows that it had been subjected to the heat of ashes, if not directly to fire. Its color is identical with that of the animal bones found near by and in undisturbed deposits.

There is no doubt that this lower jaw belongs to the layer in which it was found, and that it is the most ancient human bone from the quaternary period in Austria.

THE DEPOSITS OF KRAPINA.

The human remains found by Gorjanović-Kramberger in the quaternary, diluvial deposits near Krapina, in Croatia, consisted of the fragments of 10 or 12 skulls, a large number of teeth, and many more or less defective other parts of the skeleton. They were in undisturbed layers, and with them were bones of a hot climate fauna (*Rhinoceros Mercki*), as well as a quantity of typical Mousterian implements. Some of the pieces of human bones are calcined; in general they are in a bad state of preservation.

THE STATION OF WILLENDORF, LOWER AUSTRIA.

Willendorf is a village on the Danube, twelve hours' journey up the river from Vienna. Traces of paleolithic man were discovered in the loess deposits to the east of the village as the earth was being removed for making brick.

The archeologically important layer, preserved in part to this day, extends like a dark ribbon in the yellowish loess at the depth of about 4 meters below the actual surface of the soil. It is separable into three strata, of which the lowest is the richest in human remains. In this horizon were found thousands of flint implements, which showed all the types of the superior paleolithic culture, with two exceptions. It also yielded some points of horn and bone. The objects showing man's work were scattered about a very extended group of fireplaces.

The cotemporary fauna is typical of the loess, consisting of *Elephas primigenius*, *Rhinoceros tichorhinus*, *Bos priscus*, *Rangifer tarandus*, *Capra ibex*, *Equus caballus*, etc. This deposit furnished thus far, according to J. N. Woldřich, but a single human bone, a fragment of a femur.

THE STATION OF PŘEDMOST, IN MORAVIA.

In the middle of the large alluvial plain of the stream *Bečva* and about 3 kilometers east of the city Přerov is a village known as Předmost, and near by is a rocky elevation called Hradisko. The base of this is surrounded with thick layers of gravel and fluvial sands, on which rest 20 meters of loess. At the depth of 2 to 3 meters below the surface of this, Wankel, Maška, and Kříž discovered twenty years ago the remains of a vast human settlement dating from the epoch of the steppes, which belonged to the extreme end of the last interglaciary period. The fauna of this station approaches already that of the last glacial period.

It is certain that man lived at Předmost contemporaneously with the mammoth. The bones of these animals are found not only below and at the same levels with the remains of man, but also above them.

The explorations at Předmost have been carried on in a thorough and scientific manner. The fauna discovered is composed of *Felis spelæa*, *Hyæna spelæa*, *Canis lagopus*, *Gulo borealis*, *Myodes torquatus*, *Elephas primigenius*, *Rhinoceros tichorinus*, *Bos primigenius* and *priscus*, *Capra ibex*, *Ovibos moschatus*, *Rangifer tarandus*, *Cervus elaphus*, *Cervus alces*, *Equus caballus*, and other less typical species. The mammoth is extraordinarily abundant, the bones of at least 800 or 900 individuals having been discovered. Archeological specimens were found in large numbers. The number of flint implements exceeds 25,000; they represent very diverse and often beautiful types of the superior paleolithic culture. The collection of objects from bone, ivory, and reindeer horn is also rich, and includes a series of

real objects of art, approaching closely the chefs-d'œuvre of the glyptic period in France. It is regrettable that a thorough description of these collections is still wanting.

The great scientific value of the Předmost finds is augmented by the discoveries of human bones. Wankel found a portion of a human lower jaw, belonging apparently to an adult female. It is preserved in the museum in Olomouc, and is undoubtedly of quaternary age. It is figured by Wankel in the Časopis Musejní Společnosti, Olomouc, 1884, page 96, and by Maška in his Der diluviale Mensch in Maehren, 1886, page 103. Besides this, Kříž, in his most recent publication (Beitrage zur Kenntniss des Quartaers in Maehren, 1903, pp. 236–268, with figures) describes a series of human skeletal remains from the Předmost excavations, found by himself, and including a skull of a 12-year-old child, 2 fragments of lower jaws from young subjects, 18 pieces of skulls, 2 humeri, 2 ulnæ, a portion of a radius, and parts of 2 femurs; in all, the remains of about 6 individuals. In front of the skull of the child are still fixed some bones and teeth of the blue fox. The conscientious methods of Kříž permit of no doubt that all these bones belong to the undisturbed quaternary layers which have yielded the numerous archeological specimens.

The discoveries of human bones by Maška at Předmost have not yet been published in detail. From personal information which the writer obtained from him, Maška found a sepulchre containing 14 complete skeletons and the remains of 6 other individuals. Ten skulls, of which 6 belonged to adults and 4 to adolescents, are completely restored. They are dolichocephalic, and those of males have well-developed supraorbital arches. The length of the femurs shows that the people were of tall stature. Hradisko furnished also some geologically recent burials, but the bones discovered by Maška are separated from all of these by plain stratigraphic evidence. The quaternary archeological deposits lay above these skeletal remains, which were found in general beneath those of a more recent origin. There were also different coloration of the bones and different modes of burial. According to Maška's records, the bodies in the quarternary burials were completely surrounded with a wall of stones, a usage practiced to this day by arctic peoples. Nevertheless the bones of blue foxes and of wolves show that these animals succeeded in gaining approach to the human bodies and in destroying some parts of them. This explains also the isolated finds of Wankel and Kříž. Nothing was found buried with the skeletons. One of the individuals, a child, had about its neck a collar made of 14 small ivory pearls, looking like those which have been recovered in the middle or Solutrean layer at Spy.

The stratigraphic evidence shows incontestably that there was at Předmost an intentional sepulcher, dating very probably to an epoch

anterior to the principal quaternary station of man, for the archeological stratum above the burials showed no sign of disturbance.

SKELETON OF BRNO (BRÜNN) MORAVIA.

In 1891 a human skeleton was found at the depth of 4½ meters in the loess, in Brno, the capital of Moravia. The surroundings had furnished, before that, bones of quaternary animals and cut flint implements. According to the publications of A. Makovský,[a] who was called to the locality immediately after the discovery of the human bones, a tusk with a shoulder blade of a mammoth lay over, and some ribs of a rhinoceros not far from, the skeleton. The latter, partly destroyed in the excavation, showed profuse decoration. There were gathered about it more than 600 pieces of the Dentalium badense, which served as a collar or a breast plate; great flat limestone disks with central perforation; 3 small, flat disks with incised marginal decorations; 3 other disks made from the ribs of the rhinoceros or the mammoth, also 3 disks cut from the molars of the latter animal, and 5 of ivory; finally there was a masculine figure or "idol," 25 cm. high, made of ivory. The skull was much damaged by the workingmen. It is extremely dolichocephalic. (Figured in Makovský's Der Mensch der Diluvialzeit, pls. VIII and IX.)

The report of Makovský proves clearly that the skeleton was found in situ in an undisturbed layer. Besides this, the Maška collection from Předmost contains several stone disks identical in character with those of the Brno burial, which points to the fact that both finds belonged to the same period. Other facts, notably the presence of the ivory "idol," range the Brno find with the "glyptic" epoch of the mammoth hunters and would make its incorporation into any other period very difficult.

The Brno skeleton and a few objects found near it present, besides other features, an intense red coloration. Makovský regarded this coloration as incontestably artificial, and Virchow expressed the opinion, based on these data, that such coloration could be produced only after the bones have become devoid of flesh, wherefore it is necessary in this case to suppose a secondary burial. As a similar feature was several times observed with skeletons from the neolithic period, the Brno bones also were attributed to this epoch. In 1902 I had occasion to examine the skeleton preserved in the Brno polytechnic school, and it was still possible to see samples of the loess which had surrounded the bones. After an examination of the whole, I came to the conclusion that the coloration of the bones and neighboring

[a] Mittheil. Anthrop. Gesellsch. in Wein, XXII, 1892, 73; Verhandle. d. Berl. Gessellsch. f. Anthrop., etc., Zeitschr. f. Ethnol., 1898, 62; Der Mensch der Diluvialzeit Mährens, Brünn, 1899.

objects was not intentional. The skull is colored in part only, and what is red shows much irregularity in the quantity of the pigment; and the same is true of the other parts of the skeleton, the large disks, some of the smaller ones, and of the Dentalium. This intense red was also communicated to the bones of animals and the teeth of a horse which lay near the body, and on these the coloration presents similar irregularities as that on the human bones. The examples of loess from next to the body contain a large number of red grains and show irregular patches of coloration. This last fact is explicable only on the hypothesis that red pigment, which does not exist naturally in the loess, was thrown about the otherwise highly-decorated body. The grains of pigment remained intact in the loess, but they disintegrated over the bones and other objects and imparted to these the red coloration.[a] This demonstrates also that in the case of the Brno skeleton we have to deal with a quaternary, intentional burial, of a nature known from several other localities in central and western Europe.

THE GUDENUSHOEHLE.

The Gudenus cavern is situated 20 kilometers northwest of the city of Krems, in the valley of the Little Krems, not far from Willendorf, in Lower Austria. The cave is 22 meters long by 2 to 3 meters in breadth and is situated 7.5 meters above the level of the stream. The deposits showed on exploration as follows:

(*a*) Layer of recent rubbish, 6 cm.

(*b*) A quaternary archeological deposit, thickest in front of the entrance and in the southern part of the cave, 28 cm.

(*c*) Cave loam, 6 cm.

(*d*) Cave loam, with many unbroken bones of animals, 26 cm.

(*f*) Sand containing no specimens, 65 cm.

(*g*) Clay, with rubbish, 22 cm.

(*h*) Bed rock.

The archeological deposit contained about 1,300 implements made of flint and numerous utensils of bone and horn of the reindeer period or Magdalenian types. The fauna of the same layer was that of the arctic-alpine climate (*Elephas primigenius*, *Rhinoceros tichorhinus*, *Bos primigenius*, *Capella rubicapra*, *Rangifer tarandus*, *Cervus elaphus*, etc.). According to Woldřich this deposit yielded also a tooth of an infant.

THE LIECHTENSTEIN CAVE.

About 20 meters west of the cave known as Bočkova-di'ra, which will be dealt with later on (see p. 387), in establishing a stone quarry, a party of workmen in 1902 came across a rock shelter, the roof of

---

[a] See in this connection A. Hrdlička, "The painting of human bones among the American Aborigines." Smithsonian Report for 1904, pp. 607–617, Pls. I–III.

which had in ancient times caved in. There was no connection between this shelter and the cave Bočkova-di'ra. The caved-in rocks lay on diluvial loam. On the 22d of March, 1904, the workingmen found human bones in a nook of the shelter and its side wall. These lay in the loam and were for the most part crushed. Among the parts better preserved is a calvarium of an adult. A skull of an adult and one of a young subject, which lay a little to one side and deeper, are almost wholly shattered. Besides the preceding the excavation yielded a lower jaw, ulna, humerus, radii, parts of the pelvic bones, a femur, tibia, clavicles, vertebræ, and pieces of ribs. Of animal bones the same layer showed, according to Knies and Maška, those of *Canis vulpes*, *Canis lagopus*, *Canis lupus*, *Ursus spelæus*, *Lepus variabilis*, *Lagomys pusillus*, *Rangifer tarandus*, *Cervus alces*, and *Bos priscus*. A further fact of importance is the recovery with the bones (which are preserved partly in the Museum in Úsov, near Olomouc and partly in the Knies collection) of several implements of stone and reindeer antlers, which are evidently of diluvial origin. In the absence of anything of archeological nature of a more recent age we have to agree with the opinion of Maška that the find consists of a triple burial, which dates, most probably, from the time of the Magdalenian culture.

II.—*Erroneous, doubtful, or insufficient indications.*

The discoveries dealt with in this chapter can not be included among those surely quaternary; they have either been thus designated through error, or it is impossible to determine their exact age on account of insufficient stratigraphic data, while in a few cases it is impossible to judge of the value of the indications given about discoveries made long time ago.

(*a*) FINDS MADE IN BOHEMIA.

Human remains of Zuzlavice.

The limestone crevices which are found on the right side of the river Volińka, near the village Zuzlavice, have been explored by the well-known paleontologist, J. N. Woldřich. According to the published accounts of this observer there were collected in two of these clefts and in the quaternary loam which covers the slope and the base of the rocks more than 9,000 fragments of bones and about 13,000 teeth of quaternary animals, representing some 170 species, and with these bones were recovered 150 implements of stone, 200 of bone, about 400 pieces of broken and in some instances worked bones, and finally a quantity of pieces of a human skull. These fragments were at the base of the rocks in a fossa, and near them were found broken bones of a rhinoceros, as well as the remains of a fireplace.

The supposed implements of stone and bone, all of which I have carefully examined, are not beyond doubt the work of man. The former are without exception fragments of quartzite, lime-stone containing quartz, and pure quartz, and resemble the fragments which are produced naturally within caves of this nature without the intervention of man. In a similar way, there is not one of the bone objects which could not be attributed to natural breaks and rubbing. The presence of a fireplace and of human bones in proximity with those of a rhinoceros at the foot of the rocks do not justify any far-reaching conclusion. They may have fallen with the talus from the plain above.

THE DISCOVERIES AT JIČÍN.

Several decades ago L. Schneider collected a great quantity of animal bones in five small caves situated in the slopes of the elevation known as Prachové, not far from the city of Jičín. These were sent to Woldřich, who reached the belief that a part of the bones showed the work of man. They resemble some from Zuzlavice, which are believed to have been worked. Conclusive proofs of the presence of man, such as fireplaces and real stone implements, are absolutely wanting; and I am not able to utilize a publication concerning some human bones sent to Woldřich from these caves at that same time, for the note contains no stratigraphic information.

THE CAVE OF PROKOPI, NEAR JINONICE.

In 1888 R. Ebenhoech sent to Woldřich animal remains from a cave situated near Praha (Prague) and at that time demolished. Woldřich saw among these again a series of primitive implements, which I can not admit.

The same deposit was examined a little later by J. Kořenský, who discovered the remains of bones of *Elephas primigenius*, *Rhinoceros tichorhinus*, *Hyæna spelæa*, *Rangifer tarandus*, and other species, with some fragments of a human skull, all cemented in a form of breccia. Kořenský did not believe this breccia to be very ancient, but Woldřich, basing his opinion on the same data, thought that the formation should be relegated to the diluvial epoch of the quaternary. I partake of the opinion of Kořenský. The human remains, mixed with animal bones, were found in a cleft in the rock, and it is impossible to be sure of how they came there. They may have reached the cleft already dissociated, and the travertin which cemented the bones may have formed much later.

THE SKULL OF MOST (BRÜX).

The Most skull was found, according to Woldřich, with some fragments of human bones and a very handsome neolithic ax in

quaternary sand. According to mine warden R. Pfeifer, the ax lay underneath 2 feet of surface loam and 1½ feet of the quaternary sand, whereas the skeleton to which the Most skull belonged was 2 feet lower. The explorations of the locality by Woodřich have shown the sand to be modern. If greater antiquity were assigned to the bones, then it would have to be accepted that they were carried from the quaternary loess into the sand. Luschan, who studied the question, arrived at no conclusion. The subject of the antiquity of the skull remains undecided.

THE PODBABA SKULL.

Podbaba is a well-known locality near Praha (Prague). From time to time excavations in this place for commercial purposes revealed recent or prehistoric burials. During the winter of 1888 the brick makers of Pobdaba brought several times to Prof. A. Frič, in Praha, bones of the reindeer, mammoth, and rhinoceros, and one day a piece of human skull. Immediately steps were taken to ascertain exactly where this came from, but Professor Frič could simply establish the fact that the specimen was found in a layer of undisturbed brick earth, at the depth of 2 meters below the surface loam. Granting that the information given by the workmen was correct, it is, in the writer's opinion, not yet proved that the skull belongs to the loess formation, for posterior dislocations and cavings-in are very frequent in this deposit.

THE LIBEŇ SKULL.

According to personal information by Dr. J. Babor, the calvarium in question came from the loess deposits in Libeň, the eighth ward of Praha, and was found in the loess immediately above the underlying silurian formation. In the brickyards of this ward discoveries of quaternary animal bones (*Rangifer tarandus*, *Arctomys marmotta*, *Hyæna spelæa*, etc.) are quite frequent. In the immediate vicinity of the Libeň skull, but at a higher level, were, it is said, pieces of other skulls and fragments of pottery. No specialist examined these finds, and their stratigraphic conditions were never thoroughly inquired into. The fragment was taken by a physician who was in no way a geologist. From him it was several years afterwards secured by Doctor Babor, but by that time a thorough examination into the subject had become impossible.

THE SKULL OF STŘEBOCHOVICE.

The news of the discovery of a human skull at Podbaba recalled to a certain proprietor of Jemnik an analogous find made five years before in a separate locality. As far as could be learned, this other

skull was dug out in a brickyard near the settlement of Střebochovice and lay 2 meters deep in the loess, with some bones of a rhinoceros. Professor Frič came to the conclusion that the appearance of the skull is not in favor of great antiquity, nevertheless, he reports it with that of Podbaba. The writer can only say that there are no reliable data by which to fix the inhumation of the skull in the loess deposit.

(*b*) Finds in Moravia.

DISCOVERIES IN THE VICINITY OF BRNO, ČERVENÁ HORA, ŠLAPANICE, HUSOVICE.

The finds of apparently ancient human remains in several other places in the vicinity of Brno besides that described under authentic discoveries, has given rise to a lively scientific controversy. Makovský believed himself justified in regarding these as quaternary stations of man. He published his views for the first time in 1887, but this was subjected in 1889 to a severe criticism by Maška. In his response which appeared in the same year, Makovský maintains his opinions. His notions concerning the quaternary of Moravia are resumed in the Bruenner Festschrift of 1899, and the writer's remarks are based principally on this publication.

At Červená Hora, a little south of Brno, traces of quaternary man were furnished to Makovský by numerous shattered bones of the mammoth, rhinoceros, horse, etc., by traces of incisions or scraping on some of these pieces, and by the evidence of the action of fire on some others. He further cites a few implements of stone and bone, a bleached and perforated fragment of the frontal bone of a horse, a portion of a Dentalium, and three pieces of primitive pottery. Finally several human skeletons were exhumed from close proximity to these objects.

So far as the worked bones are concerned, I must declare that I have seen no piece in the collection of the polytechnic school in Brno which would be incontestably a manufactured instrument or whose form and condition of preservation could not be explained by natural causes, such as pressure, rubbing, gnawing by animals, etc. Layers of charcoal and bones incrusted with ashes exist, as Mr. Makovský mentions. Similar finds were made in many of the brickyards about Brno; Maška equally affirms their existence. The writer himself has seen them at Brno and in the loess at Krems (Lower Austria); E. Schumacher encountered them in the loess of Alsace. They occur, as here, at points where there is no other reason to affirm the presence of man. These phenomena are explainable by fires of the steppes, caused either by the quaternary man or by lightning. According to this hypothesis, we should have to deal in these cases with fires other than those of human beings. I adopt this explanation on account

of the aspect of the bones that are incrusted with ashes. These bones show very superficial and uniform burns, different from those observable on bones from authentic quaternary stations of man (e. g., those from Předmost), which are irregular and often exist only on the side exposed to the fire. The flint implements from Červená Hora consist merely of two formless flakes; the piece of perforated frontal of a horse is no more than a fragment of bone damaged by the teeth of a hyena and later on perforated by insects. The fossil dentalia are not rare in Moravia, and the three jars of pottery of which Makovský speaks belong to the commencement of the neolithic period.

The human bones at Červená Hora were discovered by workmen in the absence of reliable witnesses. Makovský learned of them only after the lapse of several months. There is nothing which would definitely connect these skeletons with the finds mentioned in the preceding section.

The discovery at Šlapanice (about 8 kilometers southeast of Brno) consisted of a skeleton, the only part preserved being a portion of the lower jaw. Precise data are wanting. It is only known that the specimen was extracted from among the bones of quaternary animals. Even this statement, however, lacks proper confirmation. What is certain is that the whole country offers numerous prehistoric burials of a more recent age, the fossæ of which were dug deep enough to penetrate into the layer which bears remains of quaternary fauna.

Much the same uncertainties exist about the skeleton found at Husovice, 4 kilometers north of Brno. The bones were found by workmen at the depth of at least 2 meters below the actual level of a sandpit. It is impossible to give this find any approximate age. Doctor Koudelka, who was concerned in the discovery, is not himself willing to concede that it is quaternary.

THE CAVE OF KOSTELÍK.

This cave contained the remains of a rich quaternary fauna and various products of the reindeer culture, but no remains of the human body. A lower jaw of an infant was found underneath an artificial platform in front of the cave, but as it came from a disturbed layer its age can not, according to Hochstetter and Szombathy, be determined.

THE LOWER JAW OF OCHOZ (MORAVIA).

This anatomically interesting specimen proceeds from a cave known as Švédův Stůl (Swede's Table), located in the Brno cave district in Moravia. This and the neighboring caves yielded numerous bones of quaternary animals, but nothing is known of the relation of these to the lower jaw. For this and other reasons the specimen must be classed with those of doubtful antiquity.

THE CAVE OF BYČISKALA.

However precious may be other discoveries in this cave, located in the environs of Kiritin, there is no value to be attached to those of human bones. Such bones have been recovered from different parts of the cave, and a radius with a tibia was found lodged in a layer which contained quaternary remains of archeological nature, while in the neighborhood of other remains were found bones of the cave bear. Notwithstanding this, the antiquity of these skeletal fragments of man is by no means established, which fact was recognized by the explorer of the cave, Doctor Wankel, himself.

THE CAVE OF JÁCHYMKA.

This cave consists of three portions or stories. In the middle portion, in a travertin breccia, were found in 1876, according to Doctor Wankel, numerous remains of quaternary industry, such as chisels, pointed teeth, etc. In the superior portion were discovered, with others, bones of reindeer, horse, and brown bear, with some flint knives and shards of pottery, as well as ashes and remains of man himself. The records of these finds can no longer be verified, and I have searched in vain for the collection.

CAVE BOČKOVA DÍRA, NEAR LOUČ.

Four and a half kilometers west of the city of Litovel, in northwestern Moravia and near the village of Louč, is encountered a vast complex of caves. The largest of these is called Bočkova Díra, though the name has been changed to that of "the cave of Prince Jan." Some explorations were made in this cave as early as 1826. Methodical examinations of the contents were undertaken in 1886 by Hochstetter and Szombathy and resulted in finding bones of quaternary animals, particularly *Felis spelaea*, *Ursus spelaeus*, *Equus caballus*, *Rangifer tarandus* and *Elephas primigenius*. With these were recovered a few archeological specimens belonging to the Reindeer epoch culture.

Besides the above, the explorers unearthed the skeletal remains of at least five human individuals, but it appears that these had no relation with the quaternary relics. One of the skulls was well preserved, dolichocephalic in type, belonging to a male of about 20 years of age. Szombathy believes the human bones to be quaternary for the reason that they were found with the bones of extinct species of animals and showed the same state of preservation. But if we take into account the fact that the human bones, a quantity of which had been discovered already in 1826, came from only 30 centimeters below the surface, that a piece of rotton cord was encountered in the same place, and that the débris of a human skull lay irregularly

among the parts of a well-preserved skeleton of a reindeer, it is best to adhere to the opinion of Maška, who believes that the soil has been disturbed. A similar state of preservation in bones of man and quaternary animals does not prove that they are of identical age, for fossilization and discoloration do not depend exclusively on the antiquity of bones, but also on the nature of the soil. Even the breccia spoken of by the authors can not be relied upon, for it can form at all times in caves that are humid constantly or periodically.

THE CAVE OF BALCAROVA SKÁLA.

This cave is a portion of the group of caverns known as Sloup, to the southeast of the Moravian village Ostrov. It was explored originally by Wankel and Kříž, without positive result. Subsequently J. Knies determined the existence of four quaternary fireplaces and found about them 280 flint implements and 25 objects from worked bone or reindeer horn. The rich quaternary fauna of the upper layers was that of the arctic-alpine climate. Mr. Knies wrote the author in 1902 that he possessed 4 pieces of human lower jaws and 3 teeth from the quaternary deposit, and hence surely diluvial. In a later note, of 1905, he thought only one of the pieces and the three teeth to be of quaternary origin.

(*c*) OTHER DISCOVERIES IN AUSTRIA-HUNGARY.

With the exception of the Gudenus-Hoehle discovery and that of Willendorf, no human bones were found thus far in Upper or Lower Austria which could be considered as quaternary, and the same is true of the littoral of the Empire.

HUNGARY.

Hungary itself has also thus far yielded no quaternary remains of the human skeleton.

At Barathégy were found bones of *Elephas primigenius* with fragments of pottery, knife blades, poignards, and several human skulls. It is also reported that in a cave named Nándor human bones were found with those of the great stag, while 2 human skulls were exhumed in the cave Nagy-Sáp. Regarding the two first-named discoveries, O. Herman pronounces himself with good reason against a quaternary age of the human bones; the reports of these explorations show plainly that there must have been a mixture of ancient with more recent objects. Besides this the observations of the explorers are insufficient and can not be utilized scientifically. As to the skulls from Nagy-Sáp, it is well established that they proceed from the loess; Luschan, and Hungarian scientists are nevertheless of the opinion that it is impossible to give a definite conclusion

concerning these bones, for it is not established how and when they became lodged in the loess.

POLAND.

THE CAVE MASZYCKA.

The cave Maszycka is located in the ravine Ojców, on the right of the river Pradnik. It contained two archeological deposits, one neolithic and one paleolithic. The remains of 4 human skeletons taken from the cave were always attributed by its explorers to the neolithic age.

THE CAVE OF WIELKIE OBORZYSKO.

This narrow fissure is also situated near Ojców. Immediately at the entrance P. J. Czarnowski came in 1902 upon a prehistoric fireplace. It was located at the depth of 70 centimeters and was intercalated between the dark surface loam and a yellow lower deposit of quaternary age. About the fireplace were numerous implements of flint, some utensils of bone, and numerous potsherds. A portion of a human cranium lay at the margin of the fireplace, and in the cranial cavity were some decomposed shells of the *Helix pomatia*. A quantity of these were also mixed with the ashes in the fireplace. The inferior, yellow layers contained bones of animals, but no traces of man or his handiwork. The indications are that the archeological specimens and the human bones are of the neolithic age, and not quaternary.

SECOND PART.—DISCOVERIES MADE IN GERMANY.

In Germany quaternary stations are much rarer than in the neighboring countries of Austria-Hungary or France, and may be explained by the position of the country between the two glacial centers, that of the North and that of the Alps.

The stations of quaternary man outside of the caves are seldom found in the loess, in which the country is poor, but in other geological formations.

The human remains range themselves either with the old paleolithic, as at the station Taubach, the industry of which is surely pre-Mousterian—or with the Solutrean (finds in loess), and Magdalenian. They are chronologically as follows:

III. Glacial period.
- 3. Interglacial period.
  - (*a*) Warm phase—Taubach.
  - (*b*) Phase of the Steppes.

IV. Glacial period.
- Postglacial time.
  - (*a*) Solutrean.
  - (*b*) Magdalenian: Andernach on the Rhine.

I. *Human remains surely quaternary.*

THE STATION AT TAUBACH.

The finds of Taubach (near Weimar) are well known. The base of the deposit at this locality was formed of gravel and sands, partly of glacial origin. Above this was a layer of tufas, having in its lower part remains of fauna contemporary with the *Elephas antiquus* and *Rhinoceros Mercki*, as well as an archeological deposit, with Mousterian, for the most part atypical implements, broken and burned bones, and fireplaces; while the upper layers showed fauna of cold climate (*Elephas primigenius*, *Rhinoceros tichorhinus*, *Rangifer tarandus*), but no traces of man. The uppermost stratum consisted of typical loess.

A. Weis found in the archeological deposit, in 1892, a tooth of a child. The specimen lay at the depth of 5.25 meters, and the authenticity of the find is beyond question. The discovery of an adult human molar was reported as having been made in the same layer, but the specimen was obtained by a workingman in the absence of scientific explorers. The writer would not dare to consider this tooth as of quaternary origin, particularly in view of the fact that frauds have been committed at this station since the commencement of its exploration. As scientific men manifested a great desire for human bones, it was not long before some one produced a whole skull, which was declared by Virchow to proceed in all probability from some neolithic burial of the region and by no means from the quaternary deposits. Neolithic flints have also been sold at this place to amateurs for truly paleolithic.

THE DEPOSIT OF ANDERNACH.

The station of Andernach is located about 20 kilometers north of Coblenz, on a terrace elevated 30 meters above the actual niveau of the Rhine. The archeological deposit was found in a layer of loam which covered an ancient and partly disintegrated flow of lava. The quartzite implements recovered show types such as are known from the upper paleolithic. With the stone objects were found numerous points—chisels, needles, and harpoons of bone and reindeer horn—some of which were decorated. The fauna was composed of *Equus caballus*, *Rangifer tarandus*, *Bos primigenius*, *Canis lagopus*, *Cervus elaphus*, *Lagopus albus*, *Lepus variabilis*, etc. With the archeological objects were discovered also two incisors of a child and seven pieces of human ribs. Their quaternary age is established beyond a doubt. The whole deposit was as if sealed up by the products of a posterior eruption of pumice stone; this layer was 5 to 6 meters in depth and covered with vegetal earth.

The finds made at Andernach are preserved in the Provincial Museum at Bonn.

ERRONEOUS, DOUBTFUL, OR INDEFINITE OBSERVATIONS.

(*a*) BAVARIA.

HUMAN REMAINS OF THE "RÄUBERHOEHLE," NEAR RATSIBONE.

This cave is situated in the valley of the Nab, at about 8 kilometers west of Ratisbon. It was explored in 1871 by O. Fraas, Ch. de Zittel, and F. de Guembel, who encountered in it a neolithic deposit with recent fauna, but on a lower level came across a quaternary stratum with remains of *Hyæna spelea*, *Ursus spelæus*, *Rangifer tarandus*, etc. There were signs that the earth had been disturbed, for bones of quaternary mammals were found in the recent deposit, and vice versa. The writer has not been able to find the rare quaternary implements of bone or reindeer horn mentioned by Zittel, and all that he could see of the flint objects were atypical flakes with relatively fresh color and fracture. Under these conditions he can not admit the existence of a paleolithic station in the cave in question. Whatever the facts may be, however, it is wholly impossible, in view of the disturbed condition of the deposits, to assign any definite age to fragments of a human skull exhumed with the other objects in this locality.

CAVE OF GAILENREUTH—CAVE OF OFNET.

The data concerning the specimens found in these caves are in neither case satisfactory, and it is necessary to place both finds among those of uncertain age.

(*b*) WURTEMBERG.

Ancient reports mention a human skull exhumed in 1833 in the "Schillerhoehle," near Wittlingen, and a second one discovered in 1834 in the "Erpfinger," or "Karls-Hoehle." There are no paleontological or stratigraphical data concerning these caves. Another cave, known as "Heppenloch," near Gutenberg, yielded remains of a human skeleton belonging, according to all indications, to the neolithic age; while a skeleton discovered in the "Bocksteinhoehle," not far from Bissingen, and believed by some to be of quaternary origin, has been shown to be that of a suicide, buried in the cave in 1739. A human femur has been discovered in a cave named "Hohlefels," near Schelklingen, in the valley of the Ach, and the same cave yielded bones of quaternary mammals, but it is not certain that the human specimen came from undisturbed quaternary deposit, and hence its age must remain uncertain.

THE SKULL OF CANNSTATT.

The derivation of the "skull of Cannstatt" (near Stuttgart) is wholly obscure. In 1700 Duke Eberhard-Louis of Wurtemberg caused explorations to be made in an oppidum near Cannstatt, which resulted in the discovery of many objects of Roman origin. At the base of the deposits were encountered bones of quaternary mammals, particularly *Ursus spelæus*, *Elephas primigenius*, and *Hyæna spelæa*. These bones were transported to the Cabinet of Natural History at Stuttgart, where they excited the highest interest and became the object of a series of publications. Dr. Solomon Ressel, aulic physician and a good osteologist, wrote the first report of the explorations (published in the year of the discovery), and in this he insists on the complete absence of the remains of man, which he searched for with care. The second scientific man who speaks of the Cannstatt finds, Doctor Spleissius, declares equally that no human bone has been recovered. Nor are later reports from the eighteenth century any less negative on this point. Finally, another court physician, Albert Gessner, affirms twice, in 1749 and 1753, that the Cannstatt excavations yielded no remains of man.

In the beginning of the nineteenth century, however, Cuvier already knew of a human lower jaw. But he writes in 1812:

> It is known that the ground was handled without precaution and that there is no knowledge as to the level at which each object was discovered.

It is not until 1835, hence one hundred and thirty-five years after the explorations, that the paleontologist F. Jaeger declares that in one of the glass cases of the Stuttgart Museum he came across a portion of a human skull lying next to some Roman vases gathered in 1700. Without describing the skull, he speaks of it, on the mere evidence of this relation with objects of other class, as having been found in the Cannstatt excavations made under the orders of the Duke Eberhard-Louis.

To the earlier reports on the subject should be added the conclusion of de Hoelder, who is absolutely certain that the skull was not found during the explorations of 1700. No one knows where it comes from, or when it was placed in the case. It may not be without interest to state here that later there was found at Cannstatt, in the vicinity of Uffkirche and near the locality where the excavations were carried on in 1700, a Roman cemetery from the early part of the middle ages, while in 1816 there was unearthed in the same neighborhood a tomb with a collective neolithic burial. This tomb was in the tufa and was decorated with fossil tusks of the mammoth. It is easy to see that one may attribute to the skull posing as that of Cannstatt almost any origin he desires.

(*c*) BADEN—HESSE.

DISCOVERIES OF HUMAN BONES AT MOOSBACH, MANNHEIM, AND SELIGENSTADT.

In 1839 H. de Mayer announced the discovery of ancient human bones at Moosbach, near Wiesbaden, without giving any information as to their age.

The two skulls of Mannheim were found, according to Schaffhausen, at the depth of 6 meters in the quaternary gravels of Neckar, near the place where this stream joins the Rhine. Schaffhausen considered the specimens as quarternary, for the reason that they were separated only a few feet from teeth of a mammoth and presented the same aspect. One of the skulls could not be preserved; the other shows small size, the capacity being 1,320 cubic centimeters.

The skull of Seligenstadt, in Hesse, belonged to a skeleton which lay 2 meters deep under modern alluvium and on quaternary gravel.

The two last-named specimens were certainly deposited in the gravel by the flooded rivers. Positive conclusions as to their age are impossible.

REMAINS OF HUMAN SKELETONS FROM LAHR.

The stratigraphy of this find, made by Ami Boué in 1823 (though possibly at a later period), is uncertain, and there are other serious doubts as to antiquity of the bones.

(*d*) ALSACE.

THE SKULL OF EGISHEIM.

If it is almost arbitrary to qualify the Cannstatt skull as quaternary, it is quite possible to apply the same conclusion to that of Egisheim. Its history is as follows:

In 1865, according to Faudel, a fragmentary human skull was found in the "normal" loess of a vineyard at the depth of $2\frac{1}{2}$ meters below the surface. Animal bones dispersed through the same geological layer belonged to the horse, ox, deer, and mammoth. The state of preservation of the human and the animal bones was the same.

All the above indications are without absolute value. Schumacher, who occupied himself more recently with the question of the age of the skull, declares that according to Faudel it was found between recent and ancient loess. Schumacher does not combat the opinion that the specimen may be quaternary.

In 1893 Gutmann discovered in a field in the vicinity of the same hill from which came the skull of Egisheim, another cranium, which is very similar to the former. In the same locality were also found four neolithic tombs. An arm bone exhumed with the

Gutmann skull and the bones from the neolithic burials both show a people of small stature. The resemblance of the Egisheim skull to those of these later discoveries makes it very probable that they are cotemporaneous, though it should be remarked that the same hill contains also other graves, ranging in age from the neolithic to those of the time of the Francs.

THE FINDS OF BOLLWEILER AND OF TAGOLSHEIM.

The former consist of seven human skeletons, more or less complete, discovered in 1869, with numerous fragments of pottery and signs of its manufacture in place. The pottery dates probably from different epochs, all postquaternary. The bones found at Tagolsheim consist of the remains of fourteen human bodies, buried in symmetrically made tombs in the loam and accompanied with some fragments of crude pottery. Evidently they, also, can not be regarded as quaternary.

(*c*) THE RHINE PROVINCE.

THE DEPOSIT OF STEETEN-AM-LAHN.

This find consists of the remains of at least eight human skeletons recovered from the upper part of the earth and débris in front of a cave. In the same layer were found numerous flint implements and bone of mammoth. The whole formed probably a part of the former contents of the cave. The age of the human bones is uncertain.

In a neighboring cave were found remains of paleolithic as well as of neolithic culture, and even of the age of metals. Fragments of human bones were dispersed nearly everywhere, but their age can not be established.

THE NEANDERTHAL MAN.

No other discovery has been so much discussed as that of the Neander valley. The latest controversy concerning this find was carried on between the geologists C. Koenen and H. Rauffe. The latter has published three studies which utilize in a masterly manner all the information that can be had from the earlier reports and from our actual geological knowledge. The writer has in a similar manner arrived at the same conclusions as Rauffe, and it will be sufficient to report the decisions of the latter.

The valley known as Neanderthal is traversed in part of its course by the stream Duessel, which in one place penetrates the Devonian limestones. This part of the valley is about 60 meters deep and the sides show numerous caves. It was in one of these, known as the small "Feldhofer Grotte," that the "Neanderthal man" was, in 1856, discovered. The cave is on the left side of the river, about 25 meters

above the actual level of the water. It presented a very regular vault, terminating in a pointed extremity. It was 3 meters broad and 2.5 meters high just behind the mouth, but this orifice itself was so constricted that it did not allow of the passage of a human body. This constricted opening, elevated above the floor of the cave, conducted to an external, prominent, irregular plateau. The floor of the cave was covered with a layer of loam (2 meters in depth), the surface of which was on the level with the lower border of entrance constriction as well as with the surface of the deposits outside of the cave. The bones of the "Neanderthal man" lay 60 centimeters below the surface in this loam. Dr. C. Fuhlrot succeeded in saving the calvarium, the two femurs, both humeri, both ulnæ (nearly complete), the right radius, the left pelvic bone, a fragment of the right scapula, five pieces of rib, and the right clavicle. The loam also contained a few small, scattered nodules of flint.

The above is all that we know in regard to the Feldhofer cave and its contents. No competent scientist has seen the skeleton in situ. The bones were discovered by workingmen, who were demolishing the cave, and when Fuhlrot arrived the loam and bones had already been thrown out of the cave, and in part precipitated into the ravine. It is not known whether the discovery was that of a complete skeleton or not, and how the bones were disposed. The loam has never been seriously examined petrographically and no one has studied in a thorough manner the interior of the cave or the crevices by which it communicated with the surface.

More recent researches concerning the cave and its contents, and particularly its crevices, have not cleared, but in some respects have rather augmented the difficulties of a definite determination of the age of the skeleton. It is certain that its exact age is in no way defined, either geologically or stratigraphically.

NEANDERTHAL MAN NO. 2.

Messrs. Rautert, Klaatsch, and Koenen have given to science a "Neanderthal man" No. 2. The age of this speciment is said to be much more recent than that of No. 1, but even thus the discovery is problematical. It consists of parts of a skeleton, without the skull, found in the loess which covers the upper plateau of the country. The bones lay at the distance of about 200 meters to the west of the Neanderthal cave, and at the depth of 50 centimeters beneath the surface. According to Rautert the loess occupied the remnant of a destroyed cave, in which case there can be no doubt that it was washed into the cave posteriorly to its deposition on the plateau. The bones may have been washed in at the same time, or they may have been buried in the cave later. Nothing was found with the skeleton which might give an indication of its age.

OTHER CAVES IN RHINE-WESTPHALIA AND IN THURINGIA.

Remains of human skeletons reported or appearing for a time as of quaternary origin were discovered in the caves "Buchenloch," near Gerolstein; the "Rauberhoehle," near Letmathe; the "Balve," on the Hoenne; the "Bilstein-Hoehlen," near Warstein; and a cave near Poessneck. A critical study has in all these instances shown a doubtful or a comparatively modern age of the specimens.

THE SKULL OF RIXDORF, IN BRANDENBURG.

Rixdorf, which is celebrated for the paleontological remains in its vicinity, has also given a human skull, which Krause held as surely quaternary. E. Friedel demonstrated subsequently that the specimen dates from the commencement of the historic epoch.

THIRD PART.—DISCOVERIES MADE IN SWITZERLAND.

The paleolithic deposits which were thus far discovered in Switzerland are without exception those of the reindeer age—that is, either Solutrean (Kesserloch) or Magdalenian (all the other stations). The investigations of Penck and Brueckner have demonstrated that man did not appear in the country until long after the maximum stage of the last (fourth) glacial period.

Quaternary remains of the human skeleton were found only in the caves of Freudenthal and Kesserloch.

I. *Human bones unquestionably quaternary.*

THE CAVE OF FREUDENTHAL.

This cavern, situated in the immediate vicinity of Schaffhausen, was explored in 1874 by Dr. H. Karsten, who found under a layer of recent débris and tufa a stratum of fragments of jurassic limestone (from 40 to 60 centimeters in depth), which lower down gave place to a brownish loam. These two levels gave the remains of *Rangifer tarandus*, *Ursus priscus*, *Ursus arctos*, *Cervus alces*, *Equus caballus*, *Capra ibex*, *Cervus elaphus*, *Cervus capreolus*, *Elephas primigenius*, and others, besides which they revealed a rich Magdalenian deposit. Here Karsten found also remains of man himself. Their stratigraphic position leaves, according to this author, no doubt as to their quaternary age; they belonged to the undisturbed Magdalenian deposits. The bones consist of a fragment of a parietal, which lay in the middle of a fireplace, not far from the lower jaw of an adolescent individual; and of a series of other fragments of skulls, jaws, and pelves. It is very desirable that the objects gathered in this cave be made the subject of a new monograph, more comprehensive than the

previous publication. They are in the possession of the Joos family in Schaffhausen.

THE CAVE OF KESSERLOCH.

It is not necessary to dilate on the paleontological and archeological importance of this station, which is located in the immediate neighborhood of the village of Thayngen, 8 kilometers northwest of Schaffhausen. The cave was explored in exemplary manner in 1874 by K. Merk, and again in 1893 by M. J. Nuesch, and since 1903 by J. Heierlei. The quaternary fauna consisted of *Felis leo*, *Felis manul* (s. *catus*), *Lyncus lynx*, *Canis lagopus*, *Gulo borealis*, *Ursus arctos*, *Elephas primigenius*, *Rhinoceros tichorhinus*, *Equus caballus*, *Equus hemionus*, *Sus scrofa*, *Rangifer tarandus*, *Cervus elaphus*, *Bos priscus*, *Bos primigenius*, etc. Flint implements were very numerous, and the same applies to those of bone and reindeer horn; some of the specimens were partly carved or engraved. They are characteristically Solutrean. As to skeletal remains of man, Merk declares expressly that he encountered in the deposit from the Reindeer epoch only a single clavicle, belonging to a young individual. A skeleton of an infant, exhumed from near the surface of the modern débris, can not be considered.

In view of the above exact old reports it is surprising that J. Nuesch found, several years ago, in the Schaffhausen Museum a skeleton of a young adult of small stature (the femur measured but 28 centimeters in length), which, according to an old label, came from Kesserloch. In the vicinity of these human bones were those of deer and pig, and fragments of pottery. They are not to be regarded as quaternary, but rather belong to the so-called Switzerland "pygmies."

II. *Indications to be discarded.*

THE STATION OF SCHWEIZERSBILD.

This celebrated shelter near Schaffhausen gave to J. Nuesch 22 tombs containing the remains of 27 persons, of whom 14 were adults and 13 were children below 7 years of age. Among the children's skeletons 3 were apparently of a recent date. Of the adult bodies several indicated people of small stature, and were classed by Kollmann as pygmies, but may merely represent the shorter individuals of a small race. The burials, excepting those of more recent age, must be attributed to the neolithic period of culture in the country. This opinion, which is shared by Nuesch, is confirmed by the discovery of neolithic burials—in which occurred individuals of very small stature—by Doctor Mandach, in 1874, in the cave Dachsenbuehl, Canton Schaffhausen.

THE ORIGIN OF THE SLAVS.[a]

By Professor Zaborowski,

Professor of ethnography, École d'Anthropologie, Paris.

I.

SEPARATION OF SLAVS FROM PROTO-ARYANS.

In another article by the present writer[b] there was discussed the question of the original home of the Greeks, the Umbro-Latins, the Gauls, and the Germans. Though history does not tell us the exact period of the departure of those peoples from the proto-Aryan territory, we can nevertheless trace them back to the very borders of that time.

The Greeks were the first to find their historic home, but the story of their migrations hither is lost. We have, however, in all probability, remains of their ancient sojourn northeast of the Adriatic, in the varied artistic potteries found in such abundance in neolithic villages, as at Butmir, near Serayevo in Bosnia.

The Umbro-Latins, who came from the northeast, may be studied at a time when they were still in close relation with the region of the Danube.[c]

The home of the proto-Gauls adjoined the proto-Aryan territory, and was formerly confounded with it. It has now been definitely located along the upper Rhine and the upper Danube, whence it reached to more or less fixed limits northward and eastward.

The original home of the proto-Germans I place, on the basis of archeological and even historical data, in the region west of the Baltic.

---

[a] Abstract, by permission of the author, from Origines des Slaves, by M. Zaborowski, in Bulletins et Mémoires de la Sociéte d'Anthropologie de Paris, Paris, 1904, 5th series, Vol. V, pt. 6, pp. 671–720.

[b] For other articles on the Slavs by Professor Zabrowski, see Revue de l'École d'Anthropologie for January, 1905; also the same Revue for January, 1906, under the title Penetration des Slaves ét Transformation Cephalique en Bohème et sur la Vistula. (The same author has in preparation similar papers on the Lithuanians and the Finns.)

[c] See Revue Scientifique, February 18, 1905.

It now remains to determine the fatherland of the Slavs. This is the most difficult task, for the first historic information concerning them discovers them already spread over vast and widely separated territories. The hypothesis that they came from Asia, or were identical with the Sarmatians, is the least tenable, being based on fanciful theories, while best-informed authors have derived them from the region of the Danube.[a] Their language, of the Satem group, could have originated only in the eastern zone of the proto-Aryan territory. The linguistic ancestors of the Slavs spread over the western part of the valley of the Danube only after the Umbro-Latins and Greeks, on the one hand, and the Gauls and Germans on the other, were either drawing away or had left that region. The Slavs came later, without being in direct contact with any of those peoples. We know that the Illyrians came from the east to occupy the Adriatic littoral, and subsequently came the Thracians, from whom the former separated. We know also that the Pannonians were the parents of the Dacians, and that the Moesians, Illyrians, Dacians, Getes, and Pannonians were all Slavs.

The principal promoter of this westward movement, the oldest constituent element of the Slavic peoples, notably north of the Danube, from Pannonia to the Baltic, and from the Elbe to the Vistula, was the people that, spreading over central and northern Europe, exclusively practiced cremation of the dead. This people was likewise the propagator of brachycephaly or short-headedness. They became known in history as the Veneti, one of the most ancient political groupings of central Europe, and in the days of Herodotus they occupied all the western districts from the Adriatic to the Danube. A close study of the Veneti has proved beyond doubt that the Slavs of the western zone of central Europe, from the Adriatic to the Elbe and the Baltic, are their descendants.

FORMATION OF THE SLAVIC TYPE ON THE DANUBE BY MODIFICATION OF PROTO-ARYAN AND THRACIAN TYPES.

If we examine the region of the Danube basin from the Alps to the Black Sea, we find the Slavs there as autochthons. If there are districts where at present none or but few Slavs live, nevertheless we always find them in proximity thereto, in places where they sought natural protection against invaders or into which they were driven. There is no other ethnic element in the Danube basin that could dispute their indigenous origin, for all other occupants are either conquerors or immigrants of later times. We know that the Dacians, the Pannonians, and the Moesians of the Roman period were ancestors of the Slavs, and there is substantial proof that those Illyrians, with

[a] Revue de l'Ecole, January, 1905.

whom the Gauls mixed four hundred years before the present era, were likewise Slavs. But when and how did the Slavs become the indigenes of the Danube basin, which as early as the eighteenth century B. C. was proto-Aryan territory?

It is known positively that the Thracians of the eastern zone of the basin spread toward the west and the Adriatic Sea, and this at about the time when the Umbro-Latins and the Greeks were still associated north of the Adriatic or were just separated. The Illyrians detached themselves from these Thracians and subsequently even drove them out from present Servia. At the same time the Dacians and Getes settled in distinct groups on Thracian territory, and it is known that till a late period their language did not materially differ from that of the Thracians. From their first movements the Thracians were doubtless mixed with some elements from parts of Asia where they themselves had lived.

The remains of Glasinac show that in 1100 B. C. the Illyrians largely preserved the characteristics of the proto-Aryans. But we also find there a new people that burned their dead and that mixed with and modified the character of the natives. The progress of this new constituent is marked by the growth of the custom of incineration of the dead and the expansion of a civilization now called Hallstadtian.

The transformation thus effected in the indigenous Illyrians and others is the point of departure for the formation of the Danubian Slavic type, distinguishing it from the proto-Aryan. Its expansion became, as it were, symbolical for that of the Slavs, although it was itself by its origin neither Aryan nor Slav. These people, whose brachycephaly extended to the neighboring countries, were the Veneti.

ORIGIN OF THE VENETI.

Herodotus mentions the Veneti in two passages. In the first (I, 196) he tells us that the Babylonian custom in every village of auctioneering handsome maidens, and with the money thus obtained from rich wooers endowing the less fair maidens and marrying them to poor men, also existed among the Veneti of Illyria. In the second passage (V, 9) he tells us that they live on the confines of the Adriatic Sea and, toward the north, adjacent to the Sigynnæ that inhabit the entire territory beyond the Danube. Both references hint at the Asiatic origin of the Veneti. Strabo is even more explicit concerning this origin.

Polybius (210–125 B. C.) relates (Book II, Chap. IV) that when the Gauls captured Rome (300 B. C.) the Veneti invaded their country—that is, the plains of the Po. He says of the Veneti (Chap. III) "they are an ancient people celebrated by the tragic poets for

their prodigious strength. Their customs and dress are nearly the same as those of the Gauls, while speaking a different language." This language, which Polybius says was neither Latin nor Gallic, could only have been a Slavic dialect. The funeral inscriptions from the Venetian village of Aquila contemporary with Strabo are Slavic, and the people of the extreme northeast of Italy still have a particular Slavic dialect, the Rhesian.

In the time of Herodotus the Veneti were associated with the Sigynnae, who settled north of the Danube and were connected with the Gauls. For while the Veneti called themselves a Median colony, the Sigynnae, on their part, had "habits resembling those of the Medes." (Herodotus V, 9.)

For another passage in Strabo (XII, 3, 12, and 25) we learn that the traditional origin of the Veneti was that they came to the Adriatic shortly after the fall of Troy (1183 B. C.), from Paphlagonia, where they were associated with the Cappadocians, after having participated in the Trojan war with the Thracians. Traversing Thracia and Illyria, they reached the Adriatic, bringing with them elements of their civilization, their large Asiatic horses, and the custom of burning their dead.

PHYSICAL CHARACTERISTICS AND ACQUIRED LANGUAGE OF THE VENETI.

An unexpected light is thus thrown on the prehistoric past of central Europe. As stated above, there was at Glasinac, to the southeast of Serajevo, a warlike Illyrian people, their customs identical with the Thracians, who mingled with a foreign race that incinerated their dead. Now, according to their number and their material, the Glasinac sepulchers date between the eleventh and fifteenth centuries B. C., and some belong to the time when the Veneti, after the Trojan war (1183 B. C.), gradually crossed Thracia to reach the country north of the Adriatic.

We know nothing directly of the physical traits of the Paphlagonians. Of the Cappadocians, however, something is known, for the Assyrians fought against them before the end of the twelfth century B. C., and they formed part of the Empire of the Medes. They had racial and linguistic affinities with the Turanian element of Hither Asia, with the Sumerians, the proto-Armenians, and the Medes. The same was probably the case with the Paphlagonians, for the ancients depicted them as very different both from the Thracians and the Gauls of Galatia. As to the Veneti, the figures on the famous stele of Watsch all show their type, with the nose concave or short and depressed at the root. Short-headed and brown, they introduced brachycephaly into the northeast of Italy, profoundly modifying the Umbro-Latins and the Gauls; and likewise from them came all the characteristics since known as Celto-Slavic, a term

which ought to abandoned. They also carried brachycephaly into the northwest and the north as far as the Baltic littoral, and that character is the principal constituent element of the present Slavic type. In Italy itself six cities are given by the ancients as Venetish, including Padua, Vicenza, Belluno, and two obscure cities in the Province of Treviso. In these Provinces inscriptions have been found which are attributed to the Veneti.[a] Similar inscriptions were noticed on rocks near Wurmlach in the eastern part of ancient Noricum. (D'Arbois, II, 79.) In Carinthia, near Dellach, bronze objects and pottery fragments were found, marked, it seems, with characters of these inscriptions. (Pauli, III, p. 62, 70.)

The language of these inscriptions would be settled if the earliest topographical names of the Veneti and the tomb inscriptions of their ancient and powerful city, Aquila, were accepted as Slavic. But even aside from this we find that in the whole Danubian region, occupied down to our era by Veneti intermixed with Gauls, there are none but Slavic tongues. These languages include elements introduced into them by the conquering Gauls of the fourth century B. C., when they fused with the Illyrians. They must, then, have existed at least since the fourth century B. C., and it is very probable that it is to one of these languages that Polybius refers as being neither Gallic nor Latin, but peculiar to the Veneti. The name Veneti in historic time, at least in the sixth century A. D., was the generic term for the Slavs north of the Carpathians. Not only did they use a Slavic language, but they played the chief rôle among the Slavs, and a knowledge of them is therefore of material assistance in tracing the advance of the Slavs.

THE VENETI AND THEIR NAME NORTH OF THE DANUBE AND ON THE BALTIC—THEIR PANNONIAN ORIGIN—IDENTITY WITH THE SLAVS.

Wherever the Veneti spread, there Slavs have lived or still dwell. The name Veneti, analogous to that of the Franks in France, and of the Variags in Russia, appears in the Pannonian city of Vindebona, Vienna, in that of the Vindelician part of Bavaria, between Switzerland and the Danube, and in that of the Wends, who still hold their own in Lusatia, notwithstanding invasions and a very active Germanization. It was transplanted without the least alteration to the Baltic littoral, where positive traces of the Veneti are preserved in the name Vindava, borne alike by a river and a city.

From the preceding facts it is clear that people of Venetish origin have dwelt since a prehistoric period north of the Carpathians, and that their name, preserved through the ages, was applied to no others

[a] Compare Carl Pauli, Altitalische Forschungen, III; D'Arbois de Jubainville, II, 57.

than the Slavs. It can now be demonstrated that these were the ancestors of the Veneti of the Adriatic, and that they penetrated even as far as the Baltic littoral at a remote period. In the center and in the north they were the propagators of the rite of cremation.

CREMATION PROPAGATED BY THE VENETI PROVES THEIR INFLUENCE AND AIDS IN TRACING THEIR MIGRATIONS.

The rite of cremation appears in the terramare of Emilia, and as the presence of this custom must have a relation to the intrusion of a foreign race, Sergi thinks that even at that time Illyrians—that is, "proto-Aryans" (or our Veneti)—had penetrated into Italy.[a] In the northeast of Italy there are circular ramparts resembling those of Bohemia, Istria, Dalmatia, Bosnia, and Herzegovina.

Cremation did not become general in Italy before the early iron age, and perhaps coincides with the first Venetish invasion. If the Italian civilization of that age is not to be attributed to the Etruscans (as Sergi is inclined to believe) the Veneti were evidently its authors. In any case, from the early iron age the Veneti had relations with Italy and with the Etruscans, and the rôle in the civilization of central Europe, hitherto attributed to the Etruscans, must be credited to them. They are the authors of the cinerary tombs of Glasinac and Sanskimost, of the cemetery of Santa Lucia in Tolmino, and of other Hallstadtian cemeteries. They are thus the originators and the propagators of the Hallstadtian civilization. There we meet with their name and with the practice of cremation and the products of that Illyrian and north Italian civilization.

A large number of amber beads from the Baltic was found at Glasinac, while objects of glass, gold, and ivory are preserved at Hallstadt, and beads of blue glass from the crematory tombs of Bosnia were transported to the Baltic. This points to a strong northward migration from Illyria and Pannonia. Having reached the Danube it followed its course as far as the Lake of Constance, entering it through the mountains of Salzburg, where Hallstadt is located, and in part through Switzerland. North of the Danube this movement ran at the same period, in part through Bohemia along the Elbe and Oder, occupying Silesia, Lusatia, Posen, and the Vistula, and finally the Baltic.

In this extensive territory there settled in the course of the Hallstadtian period a population less warlike than the Gauls and the Germans and more sedentary, its chief point of distinction being the religious rite of burning all its dead. It used iron and bronze ornaments of the Hallstadtian type and also received the products of the Mediterranean civilization, while its cinerary vases and urns and

[a] Arii et Italici, 1898, p. 134.

articles of amber and bone were of home manufacture. This colonization preceded the civilization of Téne and the conquests of the Gauls on the Danube and in Illyria. These cremationists never quitted the soil thus colonized about the end of the eighth century B. C. Their connection with the Adriatic has never since been broken, and neither the Gauls nor the Germans have definitely dispossessed them.

The present Slavic peoples of the West will be shown to be the descendants of these immigrants of the Hallstadtian period, and consequently they themselves were Slavs.

II.

CLOSE RELATION OF CINERARY TOMBS WITH THE VENETI.

Cinerary sepulchers have been discovered wherever the Veneti have gone. From information furnished by Tacitus,[a] added to that by Journandes,[b] it follows that the Veneti, driven by the Goths from the lower Vistula, were forced to the east of that river. They mixed with peoples who buried their dead. When Tacitus says that the Veneti were in contact with the Sarmatians he speaks, without doubt, of the Lithuanians along the Narew River. Traces of cemeteries with cinerary urns are also found to the north of the Bog and in Courland. The Veneti have also communicated somewhat of their physical characteristics to the Finns who were settled in the littoral, and the Lithuanians who occupied the interior. It is at least possible that the crania of the ancient tombs in the vicinity of Wenden were brachycephalic.

Various modes and arrangements of cinerary cemeteries have been observed in the ancient seats of the Veneti. The cineraries north of the Danube, in Bohemia, Moravia, on the Elbe, the Oder, and the Vistula as far as the Baltic are like those of the Adriatic, Pannonia, Bosnia, and Italy. According to a recent comparative study[c] of the cinerary urns of various regions, the first and most important group, that of Lusatia, recalls all the types of those of Illyria and also some of Italy. The second group, that of Aurith, on the right bank of the Oder, south of Frankfort, shows resemblances to the types of Lusatia of a certain zone, extending from Saxony through Posen as far as western Prussia. A third group, that of Goeritz, likewise on the right bank of the Oder, north of Frankfort, has also for its basis the type of Lusatia and includes urns identical with those of Illyria and Italy. The fourth group, that of the large cemetery of Billendorf, in the district of Sorau, also comprises specimens much akin to those of Villanova in Italy.

---

[a] Germania, XLIII.

[b] Histoire des Goths, II.

[c] Voss. Zeitschrift für Ethnologie, 1903, p. 167.

MIGRATIONS OF CREMATIONISTS—TERRITORY OF FIGURED URNS.

We can follow the movement of the cremationists from Pannonia, their starting point, to Moravia, Bohemia, Silesia, along the Oder through Billendorf, Lusatia, from the Oder to the Vistula through the territory of Goeritz, which reaches to Pomerania and western Prussia, and finally to the lower Vistula and the Baltic. All these regions thus traversed and occupied have intimate relations with one another; the urns characteristic of each of them blend with and cross one another. Figured urns are peculiar to the lower Vistula as far as Silesia, though they are also found of a somewhat different kind in the cemetery of Kuffarn, in lower Austria. The tombs of the lower Vistula are more or less quadrangular chambers, made of and covered with flagstones. Each tomb contains several urns. The oldest tombs are surmounted by stone tumuli resembling those of Bosnia. Later the stone tumuli give place to those of earth; at Glasinac they consisted of a heap of stones mixed with earth.

The circumference of the urns is greater than their height and the opening is comparatively narrow. They are handmade, of clay mixed with pounded granite, and unevenly baked. They vary greatly in size. Some ornamentation or a simple groove divides the body from the neck, the surface of which is often carefully polished, in contrast to the rough and grained body. At the base of the neck there are frequently two handles. Their color is generally reddish gray from the baking, but they are completely or partially covered with a black tint. Their covers are basin-shaped. They are of good depth and identical with the cinerary urns of Italy. Each contains the débris of calcinated bones of a single individual, without any admixture of ashes, though they are occasionally filled full with earth.

CREMATIONISTS OF VENETISH ORIGIN PENETRATED AS FAR AS THE BALTIC DURING THE HALLSTADTIAN PERIOD.

With the calcinated bones are often found beads, pins, fibulæ, rings, chainlets, and other ornaments. The beads are of blue glass, bone, or clay. The pins, pincers, clasps or fibulæ are of bronze. Iron appears exceptionally in the form of small rings and uncertain ornaments. The glass beads are the same as those of Illyria. The metal objects, as well as the beads, are of foreign manufacture and consequently of the same origin. The type of industry represented in the tombs, which represents two specimens of iron to seven of bronze, is purely Hallstadtian. At Hallstadt itself the cremations, numbering 455, were less numerous than the burials. The immigrants who brought the custom of cremation to the Noric Alps were not the masters there, for the Gauls continued in the majority. The same was

the case in Bohemia. But northward, in the forest region between the Oder and Vistula, on the Baltic littoral and the left bank of the Vistula, they were in full possession of the country. Their crematory tombs are imposing in number. In western Prussia alone the cremations represented by these sepulchers are estimated at 200,000.[a]

BOX-SHAPED TOMBS AND THEIR FIGURED URNS—COVERS FREQUENTLY IN THE SHAPE OF HEADGEAR.

One of these tombs without a tumulus has a paved floor and held at least 200 urns. Apart from this exception they are of the average size; that is, 40 to 75 centimeters in height by 60 to 150 centimeters in length, with the roof about 50 centimeters below the surface of the ground. The urns are there buried in the sand, as in Italy. Some are decorated with a human head, nearly always modeled on the raised paté of the upper rim of the neck. The figures include the eyes, indicated in various ways; the nose, generally jutting out without regularity of form; and the ears. The mouth is not always represented. The ears bear rings of bronze wire with beads of glass, amber, or clay. The covers of the urns are frequently shaped like a saucer or a more or less deep basin, though more frequently they have the form of headgear, such as flat caps, or round hats, either with a narrow brim or wide turned-up rims like the felt hats now in use. Some resemble the hats worn in the north of Italy during the Etruscan period. Even in Greece, where as a rule the head was uncovered, sailors and old and sick people frequently wore a rimless cap of felt, leather, or straw, called *pilos*, and in Bœotia, at least, there was in use a hat with turned-up rims called *Kyne*. This was, no doubt, transplanted to the Balkan Peninsula and the north of the Adriatic.

The interesting point for our consideration is that the headgear, in all the variations of form worn during the Hallstadtian period, is common among the present inhabitants of the region of the box-shaped tombs. It will, moreover, be seen that this is not the only Hallstadtian custom that survived in Bohemia, Moravia, in the Carpathians, and on the Vistula, showing that the Slavs of these regions are in all likelihood the direct descendants of the immigrants who introduced cremation.

EXPANSION OF EXCLUSIVELY CINERARY CEMETERIES CORRESPONDS WITH THE SPREAD OF THE VENETI.

The builders of the crematory tombs on the sandy heights of the left bank of the Vistula, as far as the Baltic littoral, were not able, it seems, to expand eastward. Extensive swamps then covered a considerable portion of both Prussias. Besides, the Esthonians were

[a] Ossowski, Monumenta, p. 101.

in the proximity of the Baltic. Consequently, cemeteries are found on the right bank of the Vistula only at a certain distance from the Baltic littoral, between Graudenz and Thorn. The basin of the Narew includes none. This would support the view that the Neures of Herodotus, that is, the Lithuanians, occupied the basin of the Narew as far as the Dniester.

The custom of cremation and of placing the débris of the bones with a few articles in urns extends as far as Scythia. It was introduced along the shores of the Black Sea in the stone period with the painted potteries of the pre-Mycenean period; but from the river San to the Dniester, cremation alone does not appear to have been practiced at any period.

Exclusively crematory cemeteries are found only where the Veneti alone were established. With the exception of the marshy littoral of Pomerania the territory on the Vistula and between the Vistula and Oder exhibits during one period only crematory sepulchers. The Veneti settled and lived there alone during many centuries, till the arrival of the Goths. In the tombs of this entire region are found the same styles of urns as on the lower Vistula; urns with figures, with their hats and caps, and of the same material which seem to prove that they are all the work of the same people.

The region between the Vistula and Oder embraces not only the south of Pomerania and Posen, but also Silesia; then Lusatia and the south of Brandenburg. From the basins of the Oder and the Vistula the crematory cemeteries extend to Moravia as far as the valley of the Vaag, and the eastern and northern parts of Bohemia; while in the western part of that country and thence toward the Saale cremation was checked by the Gauls, who kept up the custom of burial.

Exclusively crematory cemeteries are then found in the region extending from Pannonia to the Adriatic littoral and the valley of the Po. And it is probable that from here one and the same people spread as far as the Baltic, having almost identical customs.

CREMATIONISTS AT PERIOD OF SPREAD OF GAULS ON THE DANUBE OR PERIOD OF THE TÉNE.

With the beginning of the Téne period important changes took place in the condition of the people. The Gauls then made their appearance south of the Danube, and that meant the cessation of exclusively crematory cemeteries. Bohemia became the center of the spread of the conquering Gauls in central Europe, so that burial obtained there the upper hand. Tombs in rows, in which the skeletons lie on the back, accompanied with iron weapons, supplanted in the west particularly the mixed sepulchers covered with tumuli. Crematory cemeteries maintained themselves in Bohemia only on the frontier of Lusatia in the east, and in Moravia. In fact, aided by

the cemeteries, we can trace with precision the phases of the conquest of the Gauls, their supremacy, their decadence, and their final absorption. Everywhere in Illyria the influence of the Gauls reveals itself by a return to the custom of burying the dead, and their subsequent assimilation is manifested by a decrease of the number of burials or even their entire abolition.

The Gauls invaded this region in the fourth century B. C., where they constituted the stock of the Yapods. Corresponding to this period of invasion there are found in the cemetery of Watsch, near Laibach, in Carniole, two kinds of contemporaneous sepulchers: First, with cinerary urns, without weapons, and with merely some scanty and poor ornaments; and second, those with skeletons resting on their backs, accompanied with weapons and numerous articles of ornament.

Two peoples thus lived side by side, one dominating the other; the one warlike, the other peaceful and oppressed. The social conditions which one school of students, supposed to have existed on the Danube only at the time of the Avars, in the sixth century A. D., must therefore already have existed in the fourth century B. C. The Gauls found in Pannonia a people given to agriculture, and consequently with little taste for arms or aptitude for war. These indigenes were oppressed and exploited by the Gauls. The series of foreign conquests comprises also that of the Avars. But the natives were not supplanted by the newcomers.

GAULS IN ILLYRIA AND PANNONIA ASSIMILATED BY THE CREMATIONISTS; PRESENT SLAVS THEIR DESCENDANTS.

As regards the first conquerors, the Gauls, they not only did not supplant or exterminate the natives, but were themselves assimilated. Other invaders were but transients, and soon left in search of less impoverished territories where booty was more abundant. Gallic words in the Slavic tongues, and Gallic types among the Bosthians, confirm the record of history.

In certain cemeteries, as in that at Jezerine, in the northwest angle of Bosnia, the struggle of the indigenes can be followed up and its final triumph established. In the Jezerine cemetery, the proportion of supulchers with burial in the first period of the Téne, was 85 per cent; in the second period, during the decline of the Téne, it fell to 40 per cent; and finally, in the third, or Roman period, it was on the point of disappearing, being only 7 per cent.

The crania collected, though insignificant in number, also bear witness to the absorption of the ancient dolichocephalous, or long-headed people, there being a proportion of three mesocephales to five brachycephales. If, then, where numerous conquerors passed through the territory, a population which had existed since the Hall-

stadtian period continued to maintain itself, there is still more reason to assume that it would survive in regions free from great conquests. When it shall be proved that in the territories where cremation alone prevailed, as in the homes of the independent Veneti, the population has never been exterminated or dispossessed, then it will also be proved (since these regions are at present Slav), first, that the Veneti were of Slavic tongue, and, second, that the Slavs settled in these very countries in the period of the Hallstadtian civilization.

III.

PRIORITY OF THE HALLSTADTIAN CEMETERIES TO CREMATION IN PANNONIA AND ILLYRIA.

It has been seen that in Pannonia the cremationists of the Hallstadtian period were, at the period of the Téne, invaded by a burying people, and that the latter almost completely disappeared toward the Roman period at the beginning of the present era.

In the north of Bohemia and in Moravia, between the Vistula and the Oder, such an intrusion of the burying people at the same period is not recorded, because no Gallic invasions there took place, and the crematory cemeteries remained long undisturbed, even down to about the present era. Considering that the number of bronze objects found in these cemeteries far surpasses those of iron, and noting the absence of arms, iron being used only for ornaments, they must be dated at least as far back as the Hallstadtian period. And since nearly identical cemeteries, with similar contents, are also found in lower Austria, it must be concluded that these finds on the Vistula represent not merely an archaic industry, which owed its continuous existence to its isolation and remoteness from intercourse, but rather that these purely crematory cemeteries north of the Danube are the work of peoples of the same origin and of the same civilization who came there during the Hallstadtian period. That the crematory cemeteries of the Vistula and the Hallstadtian cemeteries of Pannonia and Illyria coincided more or less in time is, moreover, evident from the fact that permanent commercial relations existed between the peoples of the Adriatic and those of the Baltic before the iron age, the Téne period, and the Gallic conquests.

In the 267 tumuli opened at Glasinac in 1895 and 1896 there were found, among other objects, 1,885 amber beads. These tombs date between 1100 and 500 B. C. The amber indicates relations between Illyria and the Baltic prior to the fifth century B. C. In Italy the custom of cremation was introduced at the latest between 1000 and 1100 B. C., more likely earlier, so that in Italy, as well as at Glasinac, there is a correspondence between the spread of this cus-

tom and the arrival of the Veneti on the Adriatic shortly after the Trojan war. On the other hand, Hallstadt is not older than the eighth or ninth century B. C.; so that the crematory cemeteries of the Adriatic preceded by several centuries those of the Vistula, and it was from the shores of the Adriatic that the custom of cremation spread, not from the basin of the Vistula.

COMMERCIAL RELATIONS BETWEEN CREMATIONISTS NORTH OF THE DANUBE AND THE BALTIC AND THOSE OF PANNONIA AND THE ADRIATIC CONTINUED DURING THE ETRUSCAN AND DOWN TO THE ROMAN PERIOD.

This is proved by the objects of Etruscan and Roman art collected in the cinerary sepulchers of the north. The interesting stele of Kuffarn, in lower Austria, doubtless belongs to Etruscan art. The scenes represented on it closely resemble those of a stele of Cestosa (near Boulogna) of the fifth century, which is Etruscan. At Burg, in the center of Lusatia, cinerary urns were found, containing two Etruscan votive chariots of bronze. In the urns of the Oder and Vistula lachrymatories and Roman glass vials were found, along with débris of calcinated bones. A bronze vase was found, among other things, near Kalisch, a city situated midway between Breslau on the Oder, to the southwest, and Plock on the Vistula, to the northeast, in the very center of the region of cinerary sepulchers and on the route by which they were propagated, from Pannonia to the Baltic. The handle of this vase is decorated in répousse with a figure of the infant Bacchus, with a cloak of a panther skin on his shoulder and holding a bunch of grapes. It is a masterpiece and evidently of Græco-Roman or early Roman art. It can be approximately dated from the fourth century B. C., when the representation of Bacchus as an infant came into vogue. In a tomb at Czarnkov on the Nortec, in the north of Posen, there was a Roman terra-cotta mask, dating probably from the beginning of the imperial period, when Roman armies campaigned in Illyria and Pannonia.

CREMATIONISTS BETWEEN VISTULA AND ODER NOT DISTURBED IN POSSESSIONS OR BUT PARTIALLY DISPOSSESSED EXCEPT BY GERMANIC INVASIONS—PERMANENCE IN BOHEMIA.

There is one proof that the builders of the crematory tombs remained independent until the arrival of the Goths on the lower Vistula. In a cemetery of the district of Wejcherovo, northwest of the mouth of the Vistula and Dantzig, on that strip of land which stretches along the Baltic, and which must have been one of the first tracts occupied by the invading Scandinavians, there was found a cinerary urn, the bottom of which was adorned with Runic characters, though these could not be deciphered and their genuineness

was contested.[a] Now the Goths possessed the Runic script, for a Gothic lance engraved by them was found at Kovel, in Volhynia; and in Roumania were found different objects with Runic signs. The Goths thus met at the mouth of the Vistula a Veneto-Slavic people that buried their dead. And it was the Goths and the other Germanic invaders who followed them, the Burgunds and the Vandals, if they may be counted among the Germans, who disturbed and drove back the peaceful Veneto-Slavs.

Cinerary tombs incased with stone disappear with these new arrivals, while the iron age fully makes its appearance, the age of the Téne with iron arms.

Did the Slavs, too, disappear about the beginning of the present era under the Germanic onslaught? No. They were but partially and only for the time supplanted. Even their tombs will again appear.

But there must first be considered the conditions existing in Bohemia, Pannonia and the Danube, prior to and during the first centuries of the present era.

In the east and north of Bohemia, the Gallic supremacy clearly imposed itself upon the cremationists from the fifth century B. C. to the first century A. D., for fields of cinerary urns, together with the industry of the beginning of the iron age, are there mingled with, or are succeeded by, fields with urns characteristic of the iron industry of Téne or of the Gauls. There is, however, no appreciable interruption of the existence of the Venetish tribes who had inhabited Bohemia since the Hallstadtian period. The Germanic conquest, while crushing the warlike Gallic element, did not destroy the indigenes or builders of the crematory tombs. Thus there are discovered in these tombs Roman influences subsequent to the Téne period, as in those between the Oder and Vistula. Such is a cemetery at Dobrikov which received cinerary urns down to the fourth century A. D., while other crematory cemeteries continued still longer in existence.

The exclusive practice of cremation continued in Bohemia, especially in the north and east, till the introduction of Christianity, and is an indication of the persistence there of customs that belonged neither to Germans nor to Gauls. The Gauls of the Téne period are represented in Bohemia, as already shown, by burial tombs in which the skeleton is laid on its back with iron weapons at the side. With the advent of Germans in the first century A. D. (just the period assigned to the entrance of the Marcomans in Bohemia), there appear on the Vistula tombs in rows, Reihengräber, which are characteristic of the Germans, particularly of the Franks.

[a] Undseet, p. 137.

In 1892, Niederle [a] asserted on good evidence that "all the fields containing urns in Bohemia belonged to a people that had been settled there from the bronze age to the Christian period." Now, it will not be difficult to establish a close ethnographic connection between this people and the Bohemian Slavs of today, and the conclusion follows that the ancestors of these Slavs were settled in Bohemia before the Gallic period of Téne, or since the Hallstadtian period—that is, since the fifth century B. C.

In the northwest of Bohemia and in Thuringia, a variable proportion of place names reveals the former presence of the Slavs. But the Germans, descending by the Elbe, probably dispossessed them at an early date. This was not the case, however, in Lusatia, where the marshy region remains in possession of the Slavic Wends even to the present day. There, as in Bohemia, the presence of cinerary urns bears witness to the permanence of the people that introduced the rite of cremation and of its historic identity with the Slavs. The same was the case in the greater portion of Silesia.

CREMATIONISTS OF HALLSTADTIAN PERIOD IN PANNONIA AND ILLYRIA, WHO MIXED WITH GAULS OF THE TÉNE PERIOD, FOUND IN ROMAN PERIOD WITH CUSTOMS INTACT.

In ancient Pannonia the cremationists were as much disturbed by a burying people as in Bohemia, but survived under even more difficult conditions.

In 1883 Prince Windischgraetz distinguished tombs of cremation and of burial side by side in the cemetery of Watsch. The former are to a great extent earlier than the latter, and pertain to the conquered people who, as evidenced from the mutual position of the graves, were indigenous, while the latter, or burial tombs, are of the conquerors. These conquerors, as we know, were the Gallic Scordisci, Taurisci, and Boii, who advanced in the fourth century B. C. from Bohemia to the south of the Danube, Pannonia, Illyria and Thrace. They mingled with the Illyrians and Thracians, and toward the beginning of the present era were to a great extent fused with them. Thus Strabo tells us (VII, 5, 2) that the Yapods, who occupied the primitive territory of the Veneti on the Adriatic, in Carniole and the present Istria, were a nation half Celtic and half Illyrian. The cemetery of Jezerine, which illustrates this gradual fusion accomplished about the Roman period, has been attributed to these Yapods; but all the Gauls were absorbed in the same way. Strabo (VII, 3, 11; 5, 2) records the destruction of the Boii, Taurisci, and Scordisci by the Getæ and Dacians, who were kindred to the conquered Illyrians and Thracians and spoke the same language. Thus

[a] Les Slaves de Race, Bulletin, 1900, p. 74.

all the Gallic tribes ended by fusing with the indigenes, and disappeared.

On the other hand, the survival of the native cremationists is definitely proved by the persistence of crematory cemeteries from the Hallstadtian epoch until after the conquest and assimilation of the Gauls—nay, down to the Roman period. Such a prolonged existence may be assigned, for instance, to the cemeteries of Jezerine, of Prozor in Croatia, Meclo in the Tyrol, Gurina in Carinthia, Idria in Istria, and Ribic in Bosnia,[a] where amber beads and Roman coins of Hadrian (117–138 A. D.) and of Antoninus (138–161 A. D.) were found in the cinerary urns alongside of beads of blue glass.

It is certainly significant thus to see in the original home of the Veneti the ancient rite of cremation triumphing over the custom of burial imported by the Gauls, and persisting as the exclusive funeral ceremony under Roman dominion, at least till the end of the second century of the present era.

IDENTIFICATION OF CREMATIONISTS OF ILLYRIA, PANNONIA AND BOHEMIA WITH ANCESTORS OF SLAVS.

This much has been established above, and it should be remembered that the natives of Pannonia and Illyria, who as early as the tenth century B. C. burned their dead, continued their existence in these countries in the presence of the Gauls and Romans. It was these cremationists, speaking a language that was neither Latin nor Gallic nor German, with whom the Romans became acquainted in Pannonia. Mixed and fused with the Dacians, they were strong enough at the time of the Roman conquest to put on foot well organized armies under brave leaders. They remained, however, very barbarous, and their national and ethnic individuality was effaced by the armies and the strong absorbing administration of Rome, though they were not exterminated. Who could they have been if they were not the ancestors of the Slavs? What could be the inscriptions of the Veneti in the northeast of Italy, which Pauli[b] was able to clearly distinguish from Etruscan inscriptions, if they were not Slavic? Pauli calls their language Illyrian. But what was this language if not the one that Polybius called the Venetish, Tacitus the Pannonian—the Slavic of the tomb inscriptions of the old Venetish city of Aquila? There is no indication of the existence in this region of any languages other than the Slavic and the two other known tongues, Gallic and Latin.

In Bohemia, especially in the east and northeast, the cremationists

[a] Wissenschaftliche Mittheilungen aus Bosnien, VII, 1900.

[b] M. Pauli, Die Veneder und ihre Schriftdenkmäler, Leipzig, 1891, p. 456.

were never completely supplanted, as evidenced by fields of cinerary urns which never entirely disappeared. The Germanic domination of the Marcomans, begun with the present era and coinciding with the introduction of burial tombs in rows, the prototype of our modern cemeteries, was directed against the Gauls, the former warlike masters of Bohemia, and had little effect on the indigenous cremationists, who were peaceful tillers of the soil.

Thus, as regards Bohemia, it is proved that crematory cemeteries continued in use from the Hallstadtian epoch through the Téne period and the Roman period, coinciding with the Germanic domination, and even after the introduction of Christianity, down to the ninth century; therefore the peoples who established these cemeteries must have continued to live in Bohemia until after the introduction of Christianity. Now the presence of the Slavs in Bohemia at the time of the Empire of the Avars is historically established. The natives whom Christianity found were Slavs; consequently, the cremationists must be identical with the Slavs, since in Bohemia, outside of the Gauls and Germans, there never were any people other than the Slavs.

Farther north, between the Oder and Vistula and on the lower Vistula, the cremationists enjoyed a longer period of tranquillity, being spared the Gallic invasions, and were therefore not disturbed in their customs. We find their ancient sepulchers containing numerous urns persisting in use until the arrival of the Goths; that is, to about the beginning of the present era.

GERMANIC TOMBS IN ROWS ON THE VISTULA, MIXED WITH CINERARY TOMBS AND OVERLAID BY THEM.

It is evident that had the Gauls gone up the Vistula, iron weapons would be found in the contemporaneous crematory and burial tombs, as on the Dniester, whither the Bastarni had gone, and on the Danube. The real introducers of iron weapons on the Vistula, as indeed on the entire eastern littoral of the Baltic, were the Germans.

The encased tombs on the lower Vistula were first succeeded by burial tombs in rows, Reihengräber, which, as has been seen, also spread in Bohemia after the arrival of the Marcomans. There is no question about these Reihengräber being German. The Germans had fibulæ peculiar to themselves, and these fibulæ, according to Montelius, are met with in the Baltic provinces on the Vistula, in the north and east of Germany, as also in Bohemia and on the Black Sea, wherever the Germans settled.[a] They disappeared on the Vis-

---

[a] Les Slaves de Race, Bulletin, 1900, p. 77.

tula in the fifth century, more than two or three centuries after the successive departure of the Goths, the Burgunds, and the Vandals. The invading Goths and Burgunds drove out the cremationists, especially from the Baltic littoral and the left bank of the Vistula. Still, the burial tombs of the conquerors are found mingled with the cinerary urns of the natives, as at Elbing on the littoral, to the right of the mouth of the Vistula. Crematory cemeteries thus maintained themselves constantly down to the seventh century A. D., and even until after the introduction of Christianity.

The Germanic peoples who settled on the Vistula did not continue their distinct individuality. Like the Gauls on the Danube, they were partially, but not completely, assimilated. Moreover, the German colonization had for its result the strengthening of their ethnic importance; yet neither was the older population, the cremationists, submerged by the Germans, for, on the contrary, they regained the mastery over all the regions first occupied, restoring their own funeral customs, as their congeners were doing in Silesia, Bohemia and Moravia, and as their congeners in Pannonia had done several centuries before.

MODERN FIELDS WITH URNS ON THE VISTULA ARE CEMETERIES OF SLAVS, FOUND THERE BY CHRISTIANITY.

Some fifty or sixty fields with urns, which are common in Bohemia and Lusatia, were discovered also on the lower Vistula, and fragments of broken urns indicate a considerable number of them on the Bog. They were found in the elevations that served as intrenchments for the Burgunds.

These tombs are the work of the natives while restoring their old customs in their homes, which for several generations had been possessed by Germanic immigrants from Scandinavia. They are comparatively modern. Some of the objects found in them do not differ much from those now in use in Slavic countries. They represent the period between the invasion of the Goths, the Burgunds and the Vandals and the introduction of Christianity.

The permanence of the cremationists is thus established by the persistence, in face of the intrusion of the burying people, of funeral customs that are the expression of peculiar creeds and conditions of existence.

Thus the Christian propaganda found there peoples who were Slavs and who cremated their dead. Historical documents show that when the Christian missionaries came in contact with the Slavs the latter were still practicing cremation. This one fact enables us to trace the genealogy of the Slavs, for they must have been identical

with the ancient Venetish cremationists. There are still further proofs that the Slavs are the descendants of the cremationists of 2,500 years ago.

IV.

CHRISTIAN PROPAGANDA ON THE ODER, IN LUSATIA, AND ON THE VISTULA, MORE OR LESS VIOLENT WORK OF GERMANY.

The first preachers and bishops sent out to convert the Slavs came to the Vistula from Germany. In their work, which was promoted by the expeditions of the German princes of the frontier, they were joined by Bohemia.

Bohemia, which was a Slavic state toward the seventh century, adopted, through its prince, the Græco-Slavic cult toward the end of the ninth century, after Rotislas, the grand duke of Moravia, had the apostles Methodius and Cyril brought before him. But the German clergy won Bohemia over to Roman Catholicism, and in the tenth century it was itself the propagator of this faith among the other Slavs of the north. It was thus only in the second half of the tenth century that Christianity began to obtain a foothold between the Oder and the Vistula, and it does not seem to have taken deep root in Pomerania before the twelfth century. Helmold, a priest of Lübeck, who was sent in 1155 to evangelize the Slavs, speaks of them as a "depraved and perverse nation," and their country is to him a land of "horror and a vast solitude." In his work, *Chronicon Slavorum*, he treats in particular of the peoples who advanced farthest eastward and were thus inclosed in the German colonies between the Elbe and the Oder. Being familiar with the Slavic tongue he put under contribution for his book such works as that of Adam of Bremen of the first half of the eleventh century; also written traditions as well as the oral narrations of old Slavs who "preserved in their memory all the deeds accomplished by the barbarians." He knows well, and admits, that the German Christians committed depredations on the heathen Slavs, which sufficiently explains why the latter so long resisted the new religion or abandoned it after having accepted it. He says, among other things:

> Of the whole Slavic nation, which is divided into provinces and principalities, the Rugii are the most obstinate in the darkness of infidelity, and they persisted in it to our time.

It is, in fact, known from the mythology of the Slavs that the Slavic inhabitants of the isle of Rugen were still attached to the cult of Svantovit in the middle of the twelfth century, and from time to time offered human victims to him, preferably Christians.

CREMATION PROSCRIBED BY CHRISTIANITY.

In a pastoral letter, written in 1108 by Archbishop Adelgott, of Magdeburg on the Elbe, in the northwest of modern Lusatia, is read:

> These cruel people, the Slavs, have risen against us. They have profaned, by their idolatry, the churches of Christ. * * * They have invaded our land. * * * They have cut off the heads of Christians and offered them as sacrifices. Their fanatics—that is, their priests—say in their feastings: "It is our Pripegala who wants these sacrifices. Let us rejoice." They say: "Christ is vanquished. The victory belongs to Pripegala, the victorious."

Pripegala, Prepiekal, is the personification of the action of burning; *prepjekac*, a word still in use in the Pannonian Slavic dialect. It is known that the Slavs before or after the burning of their dead offered sacrifices and united in a funeral meal, *Tryzna*. This custom was in vogue with the Slavs of the Dnieper, as well as with those of the Oder.

In the Chronique de Nestor (p. 67, edition Leger) is read the following account:

> Vladimir (who was about to be converted) went to Kiev to offer with his people sacrifices to the idols. The old people and the idols said: "Let us draw by lots a young man and a young maiden, and upon whom the lot shall fall shall be sacrificed to the gods." The lot fell to the son of a Christian Variag. The father refused to deliver his son and locked himself up with him in his home. They were both slain. "In another case, Vladimir desiring to offer sacrifices to Perun, Dazbog, etc., the people offered their sons and daughters. * * *"

From documents collected in 1868 by Kotliarevski it follows that the pagan Slavs of the Dnieper, who practiced both burial and cremation, not only held banquets in honor of the dead, *Tryzna*, "meal of the dead," but also offered sacrifices. The women in particular allowed themselves to be burned on the funeral pyre of their husbands. According to a document relating to the destruction of paganism in Novgorod (988), the most usual sacrifice consisted in the killing of horses. As regards the cremating of the dead, the Chronique de Nestor is positive:

> When one of the Radimitches died they celebrated a *tryzna* around the corpse, then they raised a great pyre, placed the dead on it and set it on fire. Afterwards they gathered the bones, put them in a small vase and placed the vase upon a column on the edge of the road. The Viatitches still follow this custom.

Ibn Fozlan, who went as ambassador in the year 922 to the Bulgarians on the Volga, relates that he assisted at the cremation of a Russian. One of those present said to him:

> You Arabs are a foolish people; you place your dead in the ground where they are devoured by animals and vermin. We burn them in an instant, that they may fly to paradise.

A Chech chronicler, Cosmas, of Prague, of the twelfth century, in relating that Brzetislas endeavored in 1092 to suppress the customs connected with the pagan cult, says:

He abolished the sepulchres made in the woods and fields and the feasts celebrated after the pagan rite in the open places and crossroads for the repose of the souls, and likewise the profane plays in which they indulged over the bodies of the dead, disturbing their manes and celebrating the mysteries. * * *

There was thus a systematic campaign against the ancient rite of cremation, for it was the expression of the opposite creed, the occasion and center of the pagan ceremonies.

What Cosmas says of the Chechs of the eleventh and twelfth centuries, Otto of Bamberg, who became acquainted with the Poles, records of the Baltic Slavs of the middle of the twelfth century. He forbids the "burying of Christians among the pagans in the woods and fields." The result of such a prohibition was the abolition of cremation when once Christianity became the master of the country.

It is needful, however, to notice that on the Vistula, as well as in Bohemia and Lusatia, elements of German origin influenced the Slavic peoples even before the official introduction of Christianity. The burying immigrants affected not only the customs and manners of the natives, but brought about important modifications in the conditions of their existence. When the first immigrants from Pannonia came to the territory between the Oder and Vistula, this entire region was still covered with dense, impenetrable forests. The clearings began with the arrival of these cremationists, who for each of their dead needed a supply of wood. They also burned the forests to provide spaces for cultivation, though this was not widely practiced, for the population grew but slowly in the centuries before the present era, and forest resources in game readily supplied the necessary food. With the invasions of the Germans, however, about the beginning of the present era, the natives found a refuge in the still intact forests, being pushed toward the south and east. Moreover, these invasions resulted in a light increase rather than a decrease of the population. The indigenes became more numerous, better equipped, more attached to the soil, and better able to hold and cultivate it. Large tracts of forest were then cleared by fire, and the population grew apace.

PERSISTENCE OF CUSTOMS, USAGES, AND DRESS OF HALLSTADTIANS ON THE UPPER VISTULA AND IN MORAVIA.

Although the rite of cremation may not have persisted everywhere down to the introduction of Christianity, yet the customs symbolized by this rite were not altered in the same degree as the changes in the conditions of existence. Here, as elsewhere, purely pagan practices

and ideas secretly survived, though the Catholic religion became dominant. As late as the thirteenth century the funeral fetes of the Gentiles, as the Polish chronicler Kadlubek testifies, still continued unimpaired. Still more must this have been the case with such customs and manners as did not concern religion. Great revolutions may take place among a people without greatly affecting the habits of life. The most simple usages are the most lasting, because of their simplicity. This is the more so with agricultural peoples, whose wants vary little, the most primitive objects and customs persisting through all external changes. It is a mere general ethnographical observation to assert that the objects found in the urn fields of Bohemia, the Oder, and the Vistula, after the introduction of iron implements and arms, are of the same material civilization as survives in these regions to the present time.

ETHNOGRAPHIC PARALLELS BETWEEN BRETONS AND INHABITANTS OF THE CARPATHIANS—THEIR HALLSTADTIAN AND GALLIC ORIGIN.

Metal ware manufactured by the Slavs, and dresses, especially in the Carpathians, are decorated in the same manner and with the same motifs as the objects of Hallstadt. The dress embroideries in Moravia and Galicia as far as the Ukrain thus recall a decorative system which was already spread with the Hallstadtian civilization. If the same costumes, the same embroideries, are met with, for instance, among the Houzouls of the Carpathians, the descendants of the Bastarni, and among the Ruthens of Galicia, on the one hand, and among the Bretons on the other, it is apparent that it is not merely a question of accidental analogy. And if these analogies can be explained in no other way than that these peoples must have preserved common models through the ages, it must also be admitted that these common models must have had the same origin, and that consequently there was a contact between the ancestors of these peoples. Now, such a contact had really taken place. The Gauls, whose center of expansion was the upper Danube and the upper Rhine, became masters of modern France during the iron age, at the Téne period, immediately after the Hallstadtian period. At that very period they mingled with the Slavs in Bohemia and the Danube, and expanded as far as the Dniester. Thus these ethnographic similarities have their source in the Hallstadtian civilization of central Europe, and for their origin the double movement of the Gauls at the beginning of the Téne period, westward on the one hand, and toward the center and the east on the other. The existence of the same ornaments, dresses, and customs in regions so widely separated as Bretagne and the Carpathians constitutes in itself a proof of their antiquity, going back to the Hallstadtian period, when alone these diverse peoples came in contact.

HEADGEAR OF HALLSTADTIAN PERIOD STILL USED ON THE UPPER VISTULA, IN MORAVIA, AND THE CARPATHIANS.

The covers of the urns are a perfect facsimile of the hat of horsemen represented in repoussé on the scabbard of a sword of Hallstadt. On the famous stele of the cemetery of Watsch, near Laibach, which is Hallstadtian, figures are represented some of which wear pointed caps similar to our cotton caps; others have toques with ornamented crowns. The stele is of Venetian manufacture, and some of the urn covers reproduce quite accurately the quoit-shaped bonnets of certain of the figures which are of the Venetish type.

The kinds of headgear thus represented are still worn by the Slavs, whose kinship with the cremationists has been otherwise established. On the Upper Vistula the hat is seen as a truncated cone, commonly worn by Italian boys. The felt hat, especially with raised or turned-up rims, remained in use in the very region of the ancient urn fields. It was such a head-cover that decorated the idols, the four-headed statues of Svantovit, such as the one found at Zbrucz in Galicia. It also survives in the Carpathians and Moravia, worn by all ages and classes. The close relation between these hats and those worn by the cremators is evidenced from the fact that they are seen only in the regions of the Hallstadtian crematory cemeteries and where urns with covers representing them are found.

This headgear represents a part of the dress and manners of the cremators who made the figured urns. As their descendants are Slavs, so they themselves were Slavs.

Kinship is based on physical relationship, though neither ethnographical elements common to two peoples nor even intellectual and moral resemblances, implying the identity of language, will always absolutely suffice to establish it. In this case, however, the question is of two peoples who in the course of time became one with no break in their existence on the same soil. Two peoples thus following one another must have some blood relationship, some kinship, even if their customs were not the same, but here the customs remained identical from age to age. Ethnographical similarities in this case therefore prove a certain bond between the peoples, one of whom was the heir of the other, and that there has been no ethnic severance, no substitution of one people for another. Still, demonstration of complete ethnic identity must, above all, rest on identity of physical characteristics of the two peoples; it must consist in a comparative study of their crania, but unfortunately we have none of these to study, for they were all cremated. We must therefore resort to indirect means to determine their probable physical characteristics.

The burying people that settled in the north during the stone

age was marked by an elongated skull, a generally high stature, and other features that permit us to term it blond dolichocephalic. In the burial tombs of Hallstadt, as also in those which appear about the beginning of the present era on the Vistula and in Bohemia, this type is exclusively found. Judging from the skeletons collected from the burial tombs, it can be said that the entire north, from the Danube to the Baltic, was occupied by this blond dolichocephalic people until several centuries into the present era.

When the cremationists ceased burning their dead the aspect of things completely changed, and their crania begin to appear. We then perceive that the inhabitants of the very regions where formerly only blond dolichocephales were found are composed in the majority, and here and there exclusively, of people of medium size with a round skull or of the brachycephalic type. It therefore follows that the cremationists were brachycephalic. Now, brachycephaly is at present the essential, in fact, the only characteristic which connects with one another the great majority of the peoples of Slavic tongue.

Those people who introduced bronze in the Occident also introduced the rite of cremation; they early mingled with the indigenes. Directly and through its influence upon the indigenes we know that that people was brachycephalic, with dark skin and medium or short stature. They spread from the Danube toward the west during the bronze age, especially toward its end. We reserve for this people the name of Liguri. Before them came another people with the same characteristics, brachycephalic and of the same origin, that settled on the Danube. For this people the name of Veneti is set apart, although it does not comprise all the brachycephales of the Danube and never belonged to those of the eastern zone of its territory.

This settlement took place, as has been seen, at the beginning of the iron or Hallstadtian age. These cremationists gain ground and gradually become masters of the territory, at least north of the Adriatic and in Pannonia. We have none of their crania, and even in the countries where they constituted the entire population we can not determine their personal appearance by direct observation, since they burned their dead. But we have the crania of their direct descendants, namely, of those who ceased cremating their dead under the influence and the injunctions of Christianity, and these crania are of the brachycephalic type. These brachycephales, who from the Danube expanded northward as far as the innermost part of Russia, can be traced wherever there are Slavs, losing somewhat only in the intensity of their primitive characteristics in proportion as they are remote from their point of departure, their center of expansion.

SCALPING IN AMERICA.[a]

By Georg Friederici.

I.

The habit among the American aborigines of scalping fallen enemies, and of carrying off the secured piece of skin and hair as a trophy, was a wholly new sight to the early American voyagers and settlers. The first edition of Herodotus, with his account of scalping among the Scythians, appeared in 1502 and was accessible to a few of the learned only, and ethnological information concerning other primitive races was wanting.

The word scalp is English and originally signified a shell or the crown of the head. Its use in the present sense is quite recent; even well toward the end of the seventeenth century one reads only of "skynnes with the heades and crownes," "cut off their haire round about," "skins of those heads," "haire skulls of his enemies," "the skin of their heads flayed off," "crowns, or haire and skinne of the head," and similar terms. In 1675, however, Josselyn employed "the hair-scalp," and since then the term came gradually into general use. In the beginning of the eighteenth century Lawson and Byrd used simply scalp, or sculp. In French, German, and Dutch writings the evolution of the term progressed also very slowly.

So far as the author could ascertain, it was Francisco de Garay who, in 1520, made the first acquaintance with the Indian habit of scalping. This occurred during De Garay's unfortunate expedition to Pánuco. The accounts are, however, so brief and the procedure was so little characteristic that only an extended knowledge of the custom enables one to recognize a mode of scalping. It consisted in this particular case in cutting off the skin of the entire head and

[a] Scalpieren und ähnliche Kriegsgebräuche in Amerika. Inaugural-Dissertation zur Erlangung der Doktorwürde der Philosophischen Fakultät der Universität Leipzig. Vorgelet von Georg Friederici. Braunschweig, Druck von Friedrich Vieweg und Sohn, 1906. Octavo, pp. vi, 1–172, with colored map, folded. Abstract, with the author's permission, of pages 1 to 76. For detailed bibliography see the original.

face, with hair and beard, which was shown to be the habit among the Chichimecs to the regions of Jalisco and Michoacan.

The first writer who gave an account of typical Indian scalping was Jacques Cartier. During his second voyage in 1535 he was shown by the natives of Hochelaga (Montreal) five scalps of their mortal enemies, the Toudamans. These scalps were already dry and stretched on small wooden hoops. The Indians of Montreal spoke the Huron-Iroquois language.

A few years later, in 1540, the habit of scalping is met with by De Soto in the south, among tribes speaking the Muskhogean. One of De Soto's men, Simón Rodriguez, was scalped near the Appalachian Bay and his comrade Roque de Yelves barely escaped the same misfortune. Alonso de Carmona gives on this occasion the first clear account of the mode in which the Indians take the scalp and of the value the trophy has for them.

The next information concerning scalping comes from Florida, in 1549, and is soon followed by the important data of Tristán de Luna on the warlike natives of Georgia and Alabama, and of Laudonnière on those of Florida. By 1565 the reports concerning the usage present already a fairly complete picture of scalping and the various details connected with it, and this picture is made more precise through the ethnologically valuable drawings of Le Moynes, preserved by De Bry.

Meanwhile the presence of the custom was reported by Ulrich Schmidel from South America. The secretary of Cabeza de Vaca was not so well informed and speaks only of cutting off the entire head; this refers very likely to the Guaycurú-Mbayá, who, in common with all related tribes of the Chaco, first cut off the heads and then scalp them.

During the last third of the sixteenth century there are scarcely any further accounts of scalping, but the first decade of the following century shows three good reports: That of Lescarbot, from Nova Scotia; that written by Captain Smith in Virginia, and that of Champlain, dealing with the territory of the St. Lawrence. Champlain's experiences and observations are especially valuable and well show the usages connected with scalping. In 1603 this author attended a great celebration of a victory by the united Algonquin, Montagnais, and Etchemin. They had secured some Iroquois scalps and with these their women performed a scalp dance. In 1609 Champlain accompanied the united Algonquin, Montagnais, and Huron on a war expedition against the Iroquois. The battle took place in the neighborhood of the present Fort Ticonderoga and the Iroquois, who for the first time faced firearms, were defeated. Here Champlain personally witnessed, with all the other horrors of Indian warfare, the scalping of the dead and of the tortured prisoners, and

he was also present at the reception of the returning victors, laden with scalps, at Tadoussac. As the flotilla of canoes neared the settlement, the women threw off their clothing and swam to the boats, where with cries of triumph they took the scalps into their care. Then followed other festivities and dances, and toward the last Champlain himself was presented with a scalp.

After Champlain the reports concerning scalping are very frequent.

II.

GEOGRAPHICAL AND CHRONOLOGICAL EXTENSION OF SCALPING—DEVELOPMENT OF THE SCALP FROM THE HEAD TROPHY—REMARKS ON HAND, EAR, AND FINGER TROPHIES.

Scalping in its commonly known form and greatest extent was, as will be shown later, largely the result of the influence of white people, who introduced firearms, which increased the fatalities in a conflict, brought the steel knife, facilitating the taking of the scalp, and finally offered scalp premiums, which so stimulated the hunt for these objects that the removing of whole heads was abandoned. It is certain that head taking preceded scalp taking and that the latter was a development from the former, induced by the inconvenience and other difficulties which attended carrying off the whole head. This is not merely a rational deduction from facts, but is confirmed in some of the old reports and by the Indians themselves, and is a logical consequence of the conception common among the Indians and many other primitive peoples that a part of the body may be equivalent to and completely represent the whole. If an enemy is killed or their own warrior dies near a settlement, then the whole body is brought over, to be maltreated to satiation in the first or receive the proper honors in the second instance. If the distance from home is greater, the body is cut into pieces that can be transported, or, if even this would be attended with difficulty, only the head and possibly a hand are brought in; while under still greater difficulties of transportation it is the jaw alone that is brought, or more commonly the scalp. This shows the signification of the scalp lock. In cases where a scalp had been taken and the head was cut off subsequently, we are confronted with a case of mutilation; such a head was never regarded as a trophy, but was maltreated and thrown away. This briefly sketched development of the practice of scalping can be followed especially well among the Algonquin.

Very good evidence for the assumption that the scalp trophy was a development of the head trophy and that the Indians were originally all head-hunters, is afforded by the native pictography. In this the scalped bodies are always represented headless.

The opinion is quite general that scalping was practiced by all the North American Indians, and that it did not exist in South America. Both of these notions are erroneous, for notwithstanding the fact that the habit spread greatly after the discovery of North America, yet there are immense stretches of the country where scalping was never in vogue, and on the other hand the usuage has been encountered in Chaco and the Guianas.

To establish exact boundaries to the regions where scalping was practiced and where it was not, is impossible, and so likewise as to the period of time. Similar difficulties are also met with in regard to head trophies and allied customs, so that all conclusions are only approximations, caused by the complete lack of records in many cases and an incompleteness of the information in others.

Farrand, in his Basis of American History, says "Scalping was a custom over the whole continent north of Mexico, except at certain points on the Pacific slope and among the Eskimo." The only unconditionally correct part of this statement is that regarding the Eskimo, among whom the habit seems actually to have been wholly unknown. Of the neighbors of the Eskimo, the Athapascan of the north and northwest practiced no scalping, while the Thlinkit did so only in a restricted and not characteristic manner. On Hudson Bay, in Labrador, and toward Newfoundland the Eskimo lived near the Algonquin and Beothuc, of which the former took many an Eskimo scalp, yet the habit was not communicated to the latter. In the eighteenth century the Nottaway, on Moose River, at that time great enemies of the Eskimo, imposed on their dependent Montagnais tribes a yearly tribute of Eskimo scalps.

The Eskimo of Bering Strait took the whole heads of their fallen enemies as trophies, but they learned this custom from the Thlinkit, and were the only branch of the people who practiced it.

Being neither scalpers nor head gatherers, the Eskimo were famed for the mutilations which they practiced on the dead bodies of their enemies. These horrible mutilations were a potent cause of the great hate felt toward the people by all the neighboring Indians. They quartered the bodies, cut or tore them into pieces, abused them, and threw the remains into the water.

The tribes of the Athapascan linguistic family, the neighbors of the Eskimo along a great stretch of the country in the north, also, as a rule and in their old abodes, never scalped. They likewise did not practice head-hunting. In only one of the many reports concerning these tribes has the writer encountered a note that one of them, the Loucheux, took off with them on one occasion as trophies the lower jaws of their fallen enemies. Even the so-called western Athapascan, namely, those who are settled west of the Rocky Mountains on the

Frazer and other rivers, did not generally practice scalping; nevertheless, some of these tribes, probably those that had relations with the more eastern peoples, have adopted the custom. These were the so-called Carriers, the Sicaunies, Talcotin, and Chilcotin. The Athapascan on the Churchill have also learned to scalp from their Algonquin neighbors.

As to the southern tribes speaking the Athapascan and including the Apache, Lipan, Navaho, etc., scalping seems also to have been originally unknown among them, but through contact and mixture (Navaho) with neighboring tribes who practiced the same, after their many wars and after the Mexicans' offers of premiums for scalps, they also adopted the custom to some degree. Ten Kate denied this, and other observers write nothing of scalping on occasions when the Apache would have surely taken the trophies had they cared for them. Even the scalpings reported from Chihuahua and Durango need not have been committed by the Apache, but may have been due to other tribes, parties from which occasionally invaded that territory. Nevertheless, there is the evidence of Gregg, Ruxton, Fröbel, Möllhausen, and Bandelier that scalps were taken by bands of the Apache and also the Lipans. The Navaho, strongly mixed, had a tradition of scalping done by their ancestors. The Hupa in California lived away from the regions of strife with the scalping eastern tribes and remained evidently free from the habit.

All the Athapascan-speaking peoples, and particularly those that lived in the north in the proximity of the Eskimo, mutilated the dead of their enemies.

The whites who came first in contact with the Algonquin found among them two classes of war trophies. The tribes on the lower St. Lawrence, in New Brunswick, Nova Scotia, along the Delaware and Chesapeake bays, down to Carolina, practiced scalping, while the Algonquin who were settled in New England and eastern New York, along the Hudson, did not scalp, but were head-hunters. However, even among the first-named tribes, the custom of scalping was by no means as fully developed and as general as it became later on, and cutting off the entire head and scalping a severed head were also observed. The tribes of the Huron-Iroquois and the Muskhogean linguistic families behaved in a similar manner.

While the Algonquin of the lower St. Lawrence, New Brunswick, Nova Scotia, and northern Maine practiced scalping at the time of the advent of the whites, those farther south, as far as New Jersey, were head-takers only. This peculiarity is explainable by the comparative isolation of the latter between the sea and the mountains on the west, and by their limited intercourse with other tribes speaking the same language. From Chesapeake Bay down to Carolina scalp-

ing was again found. These Algonquin were separated from those speaking the same language farther north by tribes speaking Iroquois and who practiced scalping, and the habit was also met with on the lower Delaware.

The great mass of the more western Algonquin became known to the whites much later and the custom of scalping was found among them fully developed. Notwithstanding this the old habit of cutting off the entire head cropped out here and there on favorable occasions; this was particularly the case at the siege of Detroit by the associated tribes under Pontiac. Finally, what has been said of the central Algonquin is also true of their relatives of the plains, the Blackfoot, Cheyenne, and Arapaho.

The Hudson Indians, who originally belonged to the scalping Algonquin, though there is no record that they have ever been observed by the whites to practice the custom, gathered for a time a peculiar kind of a war trophy, namely, the hand. The development of this peculiarity can be traced to the introduction by the Dutch of negro slaves and the reward offered by the owners, according to a widespread habit in Africa, for the right hand of every slave fugitive. The Indians engaged in the pursuit of such fugitives just as the whites did. Later on, when difficulties arose between the whites and some of the natives a reward was set by the former on the hands of the Indians, and in the so-called Esopus war hands of the fallen were cut off and carried away as trophies both by the Hollanders and by the Indians. With, or even before, the end of the Dutch dominion the usage ceased and was eventually replaced by the practice of taking scalps, for which premiums were offered by the English.

The Newfoundland Beothuc exercised, according to Thevet, the custom of scalping in its primitive form.

The Huron-Iroquois were accused of being the probable originators of scalping in North America, but it seems that if there was any single point where the practice was developed and from whence it spread, it must be placed farther south, toward the Gulf of Mexico. It was common at the time of the discovery in Florida, and its spreading thence would also explain its occurrence in the Guianas. The Iroquois may have acquired the custom through the Cherokee, whose legends speak of it as of an old habit, and through the Tuscarora and Susquehannock.

Among the peoples speaking the Timucua and Muskhogee scalping was found by the first whites to be general. In fact, the custom extended all over the territory of the present Gulf States, on both sides of the Mississippi, among the Natchez and Tonika tribes, and farther on to the Caddo of Texas. In the last-named territory a good illustration of the mode of the development of the practice was furnished

by the Ceni. On return from one of their war expeditions the warriors brought some scalps, but the women who accompanied them and with whom it was not of such importance to go unencumbered carried whole heads of the enemies.

With the tribes of the Sioux family whites came into contact relatively late, but from all the extant accounts of these tribes it may be safely concluded that scalping was quite common, though of a later development than among the Huron-Iroquois and the Muskhogee. The western Sioux were known up to comparatively recent times to cut off on some occasions the entire heads of the fallen and then scalp them leisurely at the first halting place.

The Osage, according to some Kiowa reports collected by Mooney, are said not to have been scalp hunters; yet we have several very good and detailed accounts of this very people, showing that they did practice scalping in the same manner as all the other Plains tribes, and that they were among those who preserved longest the ceremonies and mourning usages connected with the trophy.

So far as the mounds in the eastern part of North America are concerned, traces of scalping were never discovered. Pieces of animal skin were found in the mounds, but never a scalp, yet all the tribes who were in the habit of taking the scalp lock knew well how to prepare it, and these trophies were often buried with their owner.

The Shoshone and Kiowa scalped to some extent, but here, as elsewhere, the custom received a stimulus through the approach of whites.

So far as the New Mexico and Arizona Pueblo are concerned, there is no mention of scalping in the reports of the first explorers, such as Marcos de Niza, Castañeda, Coronado, or Espejo; but later reports permit the conclusion that scalping was nevertheless quite an old custom among them, though practiced in a primitive and less striking form.

Of the tribes speaking the Piman dialects, some scalped and some did not. Among the former were the Opata and Papago, among the latter the Pima themselves and the Acaxee. Of the Yuma speaking peoples the Mohave, Yuma, and Seri scalped in a primitive manner, while the tribes of the Californian peninsula, though showing certain hair cult, were head and not scalp hunters.

In California, which was occupied by tribes of more than a dozen linguistic families, some of the peoples scalped, others took head trophies, still others eyes or ears, while some took no trophies at all. To give details concerning the many individual tribes is impossible. Neither the scalping nor the head hunting appears to have been practiced intensely or characteristically. So far as the ear trophies are concerned, it is possible that the custom originated in this region. It was practiced extensively in California, Arizona,

New Mexico, and northern Mexico by the Spanish soldiers. The writer has not found that the habit existed anywhere else in North America, except as a punishment for marital infelicity. In one instance it was observed, under special circumstances, among the Aztecs. On the other hand, the ear trophy was very common under Portuguese and Brazilian dominion in South America, and ears were delivered to the authorities by Indians, mixed breeds, and whites. We learn that as late as the first half of the nineteenth century a Brazilian commander brought in 300 ears.

The custom of taking the eyes of the fallen as trophies was also very nearly limited to a part of California, being found in addition only among the Tupi. The eyes were taken out, prepared in a special manner, and preserved in memory of the victory.

Information concerning war customs among the tribes in the Northwest is also not definite. As Lewis and Clark reached the territory of the Shahaptin and Chinook, they were surprised to find for the first time since leaving the Mississippi an absence of scalping and the presence of finger trophies. It seems, however, that the finger trophy custom was not widespread or followed to more than a moderate degree. It was apparently a remnant of a practice that was more widely distributed in the West before the advent of scalping. After the visit of Lewis and Clark, tribes like the Nez Percé, Flathead, Kutenay, and Cayuse carried on scalping.

The cutting off of fingers was found also among other American tribes, some of which lived far apart. It was reported from the Iroquois, Huron, Algonquin, and Tupi, but in most of these cases the object was not to secure a trophy, but rather to mutilate the dead body, partly as a result of hate and partly as a precautionary measure to prevent harm by the spirit of the killed. The severed fingers were especially those used in arrow release. The Araukanian employed fingers cut off from their enemies in their symbolical declaration of war.

Regarding the coast tribes of Washington and northward to the boundaries of the Eskimo, we have many seemingly contradictory statements. Nevertheless by a close study of these it is possible to arrive at some facts.

The warlike Chimakuan tribes were head-hunters, but later on practiced scalping. The Salish, Aht, or Wakash tribes, the Haida, Tsimshian, and Koloshan were all originally head-hunters, but in later times adopted here and there scalping after an intermediary form of procedure. They never practiced scalping to any great extent or in its characteristic form.

In Mexico the farther south we go the more rare the habit of scalp-becomes; its place is occupied by the head trophy.

So much for the distribution of the custom in North America.

In South America we find two foci where the habit of scalping prevailed, namely, in northern Argentina, Paraguay, Chaco, and the Guayanas. The method here consisted of decapitation (cutting off the entire head) and then the painstaking removal of the scalp; and in general it underwent no change during several hundred years. The scalp lock was also not as highly prized as among the Indians in North America. It is true that it was an object of pursuit and regard, worn by the women in the scalp dance and flaunted at the enemy before combat; but, besides the scalp, there could be found in the hut of the Chaco Indians also other trophies, such as skulls, calvaria, pieces of skin, prepared beards, etc. Furthermore, the custom did not spread in time to any large extent. The trophy of the majority of the South American tribes was the whole head. The limited extent of the practice of scalping even among the Chaco peoples can probably be attributed to the absence of firearms and steel knives, as well as that of scalp premiums, such as were offered elsewhere by the whites. The absence of firearms was due to strict rules made by the Spanish against their introduction among the natives.

Concerning Guiana, we have the trustworthy statement of Stedman that scalping was practiced by the Carib. As to the Antilles we know but little. Columbus found some heads, in all probabilities trophies, in the dwellings of the aborigines of eastern Cuba. On his second voyage his men found the heads of their comrades, who had been left ashore and were killed by the natives, in the hands of the Haitian. Chanca found skull trophies among the Carib of Guadalupe, and in another place we read of a head in a cooking pot. The boiling of the head served to make its cleaning easier. Besides heads, there were found in the huts of the Carib the whole upper part of the skeleton, flutes made from human bones, and arrow points from the same material. According to all indications, the head was the principal form of trophy all over the Antilles and even in the Guianas.

The negroes of the Guianas and the Maroons in the Antilles brought with them their own forms of trophies. These were first of all prepared right hands, but also heads, with which the negroes played ninepins, and lower jaws, with portions of the scalp, which were used in witchcraft practices. Pinckard reports, however, even true scalping among the Bushmen settled in the Guianas, though no such custom was met there previously by Stedman.

The question arises as to how the occurrence of scalping in the Guianas is to be explained. It was not introduced by the negroes, for, with the exception of its occurrence in the nineteenth century in Dahomey, it was not known on the Dark Continent. The custom was highly developed among the Timucua peoples in Florida, yet the

theory that it may have thence been transmitted to Guiana finds no substantial support. In a similar way there is no evidence that it was introduced by the whites. On the other hand, it does not seem improbable that it was brought in through the slave trade; that is, through enslaved Indians brought to Guiana from North America. Indian slaves from New England, Carolina, Georgia, and Florida were far dispersed by the whites, and a portion of them were brought to the mouth of the Orinoco and the shore of South America for pearl fishing. It is quite possible that some individuals or parties from among these Indians, most of whom belonged to scalping tribes, gained their liberty and, joining some of the natives, introduced the custom of scalping among them. The source of the practice in Chaco is not traceable.

SPREADING AND DEVELOPMENT OF THE CUSTOM OF SCALPING THROUGH THE INFLUENCE OF EUROPEANS.

It is a well-established fact that the conflicts of primitive peoples, while very frequent, are in general not attended by many fatalities. The same was true of the Indians, with the exception of the very infrequent instances of a success of an attack by surprise, which was followed by a general massacre.

The introduction of firearms changed this state of affairs. The guns became not only the direct cause of a greater number of fatalities, but they also served to demoralize the party armed in a more primitive manner and facilitated pursuit. In consequence the wars became more bloody and there were more scalps.

In North America the natives were supplied with firearms by the colonists themselves, in some cases surreptitiously, in others openly. They were also furnished with the iron or steel knife, which greatly facilitated the removal of the scalp lock. Formerly the scalping was done with knives made of various materials. The reed knife was found in Brazil, Guiana, and the southeastern part of North America; the shell knife was used along the entire Gulf and north along the Atlantic coast as far as the territory of the Huron-Iroquois, also to some extent on the Pacific coast and among the Araukanians; a fish-tooth knife existed in the Chaco, throughout Brazil and the Guianas; and a stone knife prevailed in Mexico and neighboring regions, in California, the Rocky Mountains, on the Plains, and in Texas. The Apache knew how to sever the scalp lock with the sinew cord of the bow. All of these implements possessed disadvantages when compared with the white man's knife, and the latter was eagerly adopted. It became a much desired article of commerce and exchange and was soon used in scalping, upon the frequency and development of which it must have exerted a stimulating effect.

The "scalping knife," or "scalp knife," had ordinarily the shape of a single-edged butcher knife, but occasionally it was two-edged, like a dirk. The traders usually sold the knife alone, the Indians making the scabbard according to their own liking. The instrument was carried in the belt or on a cord passing about the neck. The prices paid for these knives differed widely. Thus, in 1665 certain Canadian Indians received 8 knives for 1 beaver skin, while in the beginning of the nineteenth century, during the height of the power of the fur companies, $7.50 was paid in their territory for a knife which in England was worth 3½ pence. At about the same period farther south, in the United States, a knife cost $1. Catlin tells us that in 1832 a Sheffield knife, worth perhaps 6 pence, was valued at the price of a horse.

While firearms and steel knives gave a strong impetus to scalping in North America, the acme of the custom was reached after the institution by whites of scalp premiums, accompanied by the employment of the natives by the whites for scalp gathering, and scalping by the whites themselves.

The first to offer premiums for the heads of their native enemies were, in 1637, the Puritans of New England. They asked for the heads, scalping being as yet unknown in that part of the country. As a result, heads of the Pequods were brought in by the colonists and allied Indians in large numbers.

Thirty-eight years after the Pequod war, began that against King Philip, and head premiums were again established. At this period the custom of scalping had already extended into New England, and most of the trophies obtained must have been scalps.

On the 15th of July, 1675, the Connecticut colonists made with one of the Narragansett chiefs a treaty in which they promised for the person of one of the feared Wampanog chiefs 40 cloth coats, or 20 for his head alone, and for each one of his subjects 2 coats if living or 1 if dead. To their own troops they paid 30 shillings for each head. To the "heroine," Hannah Dustin, who with her own hands is said to have taken and brought in the scalps of 2 Indian men, 2 women, and 6 children, the colony paid £50, besides which she received many expressions of thanks and numerous gifts, including a substantial one from Governor Nicholson.

In 1680 scalp prizes were offered by the colonists of South Carolina; in 1689 they offered the high sum of £8 for each scalp of an Indian warrior. About this time we hear for the first time of scalp premiums offered by the French. In 1688 the French Canadians paid for every scalp of their enemies, whether white or Indian, 10 beaver skins, which was also a high price, equivalent in Montreal to the price of a gun with 4 pounds of powder and 40 pounds of lead.

Later on, about 1691, the governor of Canada paid 10 crowns for every scalp, 20 crowns for every white male captive, and 10 crowns for a white female captive. Later on the scalp as well as the captive price was lowered to 1 crown each, though the government officials declared that 10 crowns for the scalp of every existing Iroquois would be a good investment for Louis XIV.

We have seen that it was the English who offered the first scalp premiums, and it was the French who first extended such rewards to the scalps of whites. This latter custom was, however, also adopted before long by the English colonists, and in 1693, but particularly in 1696, premiums were offered explicitly for French scalps. The price per scalp, perhaps on account of the poor Canadian treasury, was always higher among the English than among the French. In 1707, during Queen Anne's war, the English increased the Indian scalp premium for those who were not employed by the government of the colonies to £100.

In 1703, during Queen Anne's war, the young French colony in Louisiana began also to offer scalp rewards, commencing with 10 crowns for each scalp. After this the prices ranged conformably with those in Canada.

In later wars in which the colonists were concerned scalp hunting was incited to still greater intensity. The premiums were large, ranging up to £100 for one scalp; and they applied to Indians as well as to white enemies. The alluring profits and the growing difficulty of securing the trophy led some to skillfully make two or even more scalps out of one, and to other, more grave, abuses; members of friendly tribes and even the white countrymen of the scalpers were not safe, and even graves were made to yield victims. In June, 1755, General Braddock guaranteed his soldiers and Indians £5 for every scalp of the enemy. A reward of $200 was prescribed for the head of the Delaware chief Shingask and £100 for that of the Jesuit Le Loutre. Scalp prices were offered by the State of Pennsylvania. On the 7th of July, 1764, Governor Penn announced the following rewards: For every captured Indian more than 10 years old, $150; for every scalp of a killed Indian, $134; for every captured woman or boy under 10 years of age and belonging to the inimical tribes, $130; and for every scalp of a slain squaw, $50.

The employment by the various colonies of friendly tribes as allies in war fostered scalping. In 1693 Frontenac ceremoniously received from Indians some scalps of the English. In 1746 Governor Clinton received and counted in an open meeting some scalps of Frenchmen, honored with a *nom de guerre* the Indian leader whose band secured them, and then had the Indians perform a war dance before him, in which William Johnson, then the Iroquois agent and later on a baronet and English general, appeared painted and half naked

with the Indians. In the French colonies the conditions were similar. Scalping was also practiced during the War of the Revolution, and that on both sides. Serious complaints were made in this regard against the English, and Hamilton, "the hair-buyer general," was on this account for a long time the object of a bitter hatred. There is no doubt that the English, who incited some of the Indians against the colonists, also offered pay for scalps, though this does not seem to have been the subject of any special law or public ruling. English commanders and generals, among others Burgoyne, received scalps in festive gatherings. In the north the English, following Sullivan's expedition, paid $8; in Georgia occasionally £3 for a scalp. So far as the colonies are concerned, among the border population scalping was general, besides which some of the legislatures offered direct premiums. Thus the legislature of South Carolina promised £75 for every scalp of the fighting men of the enemy, £100 for every captured Indian, and £80 for every captured Englishman or negro.

* * * * * * *

In Mexico the first offers of head premiums of which the writer could find a record date from 1616 to 1618, preceding, therefore, by twenty years similar rewards given by the New Englanders during the Pequod war. The occasion for the Mexican offers was the Tepehuane rebellion in the State of Durango. During the eighteenth century, particularly toward its close, and in the beginning of the nineteenth, scalps, which to prevent frauds had to show both ears, seem to have had a definite market value in northern Mexico, but exact data on the subject are wanting. During the second third of the nineteenth century reports concerning scalping are more frequent. In 1835 the legislature of Sonora proclaimed a war of extermination against the Apaches and set the reward of $100 for every Apache scalp. Chihuahua followed in 1837 with an offer of $100 for every scalp of a male, $50 for that of a female, and $25 for that of every Indian child. In 1845 these scalp regulations were also adopted by the other north Mexican States, as a result of which numbers of adventurers formed themselves into scalp-hunting bands. Kirker, the leader of one such, had in the very beginning, through surprising an Indian camp, such success that the treasuries were able to pay him only a part of the scalp money.

In 1848 and succeeding years the conditions became still worse. It was decided in Chihuahua to again employ bands of scalp hunters, and the premiums were advanced to $250 for each captured full-grown Indian or $200 for his scalp; $150 for every captured Indian woman or child under 14 years of age or $100 for each of their scalps, in addition to which the offers carried the right to the spoil. The privilege granted was often abused by the bands, and scalps were taken from other Indians besides the enemies and even from Mexican

mestizos, the hair and skin of which can not, in many cases, be distinguished from those of full bloods.

Such a state of affairs lasted for several decades, continuing past the French invasion and well up to the eighties. The rewards offered reached, in 1863 to 1870, the large sums of $200 to $300 for each ordinary scalp and $500 for that of a chief of the Indians.

In Central and South America we find no scalp premiums and no scalp hunting.

The part of the white population most directly concerned in scalping were the frontiersmen, with the hunters, trappers, and miners. Their mode of life and their frequent dealings with the Indians, of friendly as well as unfriendly nature, developed in these men and even women, who were for the most part the descendants of the Scotch-Irish, manners which were not always in accord with those of civilization. * * *

In some cases the Indians and after them the whites severed not only the scalp, but also other hairy parts of the skin or other pieces, and some of these were utilized for tobacco pouches, straps, belts, etc. Such pieces of skin became even, in some instances, articles of trade. In the summer of 1779 the farmers in the neighborhood of Prickets Fort, in West Virginia, killed an Indian who was wounded in a fight, and the body was scalped and skinned. The skin was tanned, and from it were made a saddle, ball bags, and belts. One of the bags is said by Mr. Thwaites to be preserved to this day by a granduncle of one of the farmers who did the skinning. But even the whites were not always safe before other whites in this respect; thus we read in Norton's Redeemed Captive that during the war in 1746 a French youth cut off an arm of a slain New Englander for the purpose of making himself a tobacco pouch.

It is but natural that a custom of such a force and duration as scalping left some permanent traces, which are best recognizable in the language. The word scalp is commonly used as a synonym for the hair-covered skin of the head. It was applied to animals, and one hears to this day about the "scalp" of the puma, bear, wolf, etc. Premiums for wolf scalps were an important item of income and expense among the colonists. In ordinary conversation the term found and to some extent still finds many applications; thus "may I never see a scalp" was a form of oath; and there were the expressions "There can be no scalping between us," "To go a-scalping," "A company of expert hair-dressers," etc. The railroad ticket "scalper" is still a well-known figure. Figuratively, the word was used to denote social conquests, etc.

At the present time scalping in North America has ceased to exist. It has been prohibited, under heavy penalties, by the law, and had to

be given up by the conquered Indians with other parts of their former culture. Curiously enough the trophy formerly so common has become a rare article, even in American ethnological museums.

ADDITIONAL NOTES.

The scalp itself deserves a few special remarks.

To the eastern Indian the scalp lock was the visible proof of personal bravery, the palpable sign of accomplished revenge; it was like his war medal gained honorably from his enemies. However, the trophy did not always remain the property of the individual warrior, for among some of the tribes it was delivered, after the completion of the proper ceremonies and dances, to the chief or the community; yet the one who took the scalp retained always the honor of the deed and the memory of this was manifested on his person by special forms of painting or other decoration. In still other cases the scalp obtained in individual combat with an enemy was the property of the warrior, while those secured after a battle were delivered to the chief or the tribe and were the subject of special disposition.

Among the western Indians the reputation of a man was proportionate to the number of "coups" or strikes which he had accomplished, and the scalp counted simply as a great "coup."

To be worthy of the full honor the warrior was obliged to personally remove the scalp. This accounts for the often reckless efforts made to secure the trophy. This tendency was disadvantageous to the Indians in their fights with whites, for the time required to sever the scalp might have been sufficient to slay several more of the enemy; it was particularly inconvenient during pursuit.

The reasons which occasionally induced a warrior to go on a scalp hunt were especially ambition, a desire to mend a damaged reputation, revenge, conceit or bravado, or eagerness of gain. Even political reasons may have been occasionally the incentive, for the quantity of scalps in a tribe's possession represented a power and would facilitate the gaining of confederates. With these must be ranged the belief in certain mystic powers identified with the scalp and supposed to be acquired with it, and the necessity of the presence of the trophy at certain ceremonies and burials.

To secure scalps the Indian shunned no distances, obstacles, hunger, or thirst, nor did he shrink even at the prospect of an almost certain death. Journeys up to 1,000 kilometers long were undertaken for the purpose; neither women nor children nor the sick or wounded were spared, and in extreme cases even the dead were disinterred and scalped. On one occasion the Indians allied with the French surprised an English field hospital and scalped all the patients. General

Jackson, not being able even with all the possible precautions to prevent the Creeks from scalping his buried soldiers, adopted the plan of sinking the dead in the river.

To save his own or his friend's scalp the Indian was ready for any sacrifice, for it was with him not simply the matter of a part of his skin, but with it of the soul itself. If it was impossible to save a friend from death at the hands of the enemy and to carry away his body, an endeavor was made to at least take away his scalp into safety. In rare cases only was a member of a tribe scalped by another member of the same for other reasons; Indians executed by their own people were never scalped. In its pure form scalping in the East could only be performed on an enemy, and was an act of national significance, a declaration of war, or a manifestation of the state of war.

The Indians of the West never scalped a suicide, and, according to Major Dodge, they also never scalped a negro; the eastern Indians were in the latter regard, it seems, less particular, for the writer came across two records of the scalping of negroes.

* * * * * * *

The return of the scalp-laden warriors to their community was announced ahead by signal fires or through a special messenger, and the whole population, but particularly the women, prepared for the reception of the party. Such a reception and the following ceremonies were, according to eyewitnesses, most striking and impressive. Among other manifestations, each scalp was greeted by a special characteristic "scalp cry."

The well-prepared scalps served many purposes. They bejeweled their owner, his horse, his tent, his weapons, while scalp or other human hair streamed from the borders of his garments. As signs of a victory they were exhibited in various ways—hung on lines, poles, or fastened to canoes, etc. They played an important rôle in numerous ceremonies, and the scalp dance or ceremony proper was among the most important and widespread of such manifestations. Finally the scalps were buried among his other honors with the warrior.

Though scalping has ceased in North America, yet the scalp dance has not been entirely abandoned. Artificial scalps take the place of the real, but the form of the ceremony is gone through with scrupulous care.

The beliefs as to the consequences of scalping on the soul of the victim differed. Among some tribes it was held that the spirit of the scalped will have no rest in the hereafter; others believed that it was bound to serve to that of the victor, while still others supposed that it was prevented from ever reaching the "happy hunting ground," or that it was wholly annihilated.

ZOOLOGY AND MEDICINE.[a]

By Raphael Blanchard,
Professor of parasitology to the Faculty of Medicine of Paris.

The subject of the present paper is not new. I might cite a considerable number of academic discourses or inaugural dissertations that discuss the relations of zoology to medicine; these literary essays attack the subject from different points of view, according to the philosophical predilections or the medical doctrines of the period; but the greater number of them soar into the nebulous heights of metaphysics and each resembles the others in the complete lack of a truly scientific basis.

In the course of the nineteenth century various sciences sprang into existence, such as comparative anatomy, physiology, anthropology, experimental medicine and parasitology, each one of which has thrown a new light upon the nature and the origin of man, and especially upon his relations with the higher vertebrates. It would certainly be a very interesting work, but one far exceeding the limits of a modest paper like this, to educe the scientific ideas that have been derived from these recent studies. I do not intend to enter into a discussion as technical as that would be and for which I have not the necessary time; I shall play a more modest part and limit myself to assisting you to put the finger upon certain examples which will show what significant advances in medical doctrines are due to zoology, what capital discoveries have resulted from a more exact knowledge of animal parasites, what an unexpected light has been shed by these new ideas upon the origin of the most fatal diseases, what fortunate practical results are derived from them, and, at this epoch of vast colonial enterprises, how much the acclimation and success of our race in hot countries are bound up with the progress of medical zoology.

[a] Translation, by permission, of a paper presented at Berne August 15, 1904, at the first general session of the Sixth International Congress of Zoology, corrected and brought up to date by the author. Original published in Compte-Rendu des Séances du Sixième Congrès International de Zoologie, Geneve, 1905.

In the blood, in the lymph, and in connective tissue are found anatomical elements which have for a long time been known under the name of "leucocytes," or white corpuscles. A well-worn comparison likens them to the Amœbæ, which they resemble, indeed, both in their method of locomotion and in the manner in which they ingest solid particles. Several varieties are known, but the distinction between them remains as yet merely a histological curiosity. Now these elements, which resemble the lowest animals in their structure and physiology, are found to play a most important part in the organism.

The physiological equilibrium that constitutes health is assured only because of their constant vigilance. Distributed to all parts of the body, they keep watch over every point and resist the various perturbations that may arise at any moment in our organs; they have for their special function the arrest of foreign bodies, of microbes, and parasites in general that invade our economy by the most various routes. According as these are greater or smaller the leucocytes vary their method of attack; they either engage singly or work in combination to arrest the advance of the parasitic invaders. If the infectious agent is not an organized body, but consists of chemical substances endowed with toxic qualities, they intervene in another manner and, adapting themselves to the new conditions, elaborate and supply to the humors of the organism substances capable of neutralizing the dangerous effects.

Is not the theory of phagocytosis, which we owe to the sagacious observations of Metchnikoff, one of the manifestations of these leucocytes? Everyone knows the nature of this theory; everyone at least knows the Amœbæ that live in stagnant waters. These animalcules present the lowest degree of animality; their sarcode or plastic substance extrudes prolongations which enable it to inclose solid particles with which it may be in contact; these are, according to their nature, either digested and assimilated by the Amœba or, on the contrary, rejected after a certain lapse of time. Nothing is better known than this phenomenon; Dujardin and others have studied it very thoroughly; they consider it as a manifestation of the simplest act of nutrition. It is so, indeed, but it is also an act of exceptional importance, since it was the point of departure for the discovery of phagocytosis, a doctrine which touches upon some of the most obscure problems of physiology.

Thus it was that a simple fact of zoological observation, well interpreted by a mind of rare penetration, completely overthrew the hesitating and misty conceptions derived from humorism, that doctrine by which medicine endeavored to explain the great fact of the resistance of the organism to infections. Phagocytosis offered the key to the problem. It also enables us, or soon will enable us, to compre-

hend in an equally clear manner the laws of vaccination and of immunity, for which medicine has never been able to advance an acceptable hypothesis.

Such are the results of the phagocytic theory. We may search in vain in any other branch of biological science for an example of so profound a revolution in doctrine, based upon so slight a phenomenon.

In 1901 our learned colleague, Prof. B. Grassi, showed to the Congress of Berlin the part which mosquitoes play in the propagation of malarial fever. I do not wish to take up again this subject, which he has treated with so much authority, but it may be useful to dwell for a moment upon these insects, which are even more dangerous than his brilliant paper indicated. In fact, they not only propagate malarial fever over almost the entire surface of the globe, but they are, in countries less vast but yet of great extent, the agents for the dissemination of maladies that rank among the greatest scourges of humanity. Throughout the whole of this Torrid Zone they inoculate with the *Filaria sanguinis*, a nematode that lives in the connective tissue or in the circulatory apparatus. Its embryos are carried along by the torrent of the blood. They have a relation to various pathological conditions, such as the hæmaturia of hot countries and the elephantiasis of the Arabs.

In a more restricted region mosquitoes inoculate with yellow fever, whose domain, formerly limited to tropical America, now extends to the western coast of Africa, sometimes touches Europe, and is perhaps on the eve of reaching the extreme East as soon as the Panama Canal is finished. Mosquitoes are not, as might be supposed, mere inert transmitters of the known or unknown parasites that cause these disorders; on the contrary, in their organism such parasites undergo more or less complicated metamorphoses.

One of the most urgent problems in the hygiene of hot countries is, then, since these facts are known, the study of the mosquitoes found in different parts of the globe. The exact knowledge of the fauna of a country, from this special point of view, is, as may be seen, of the greatest interest for public health, since the country that is the object of such an investigation may be declared dangerous or healthy according as the species recognized as pathogenic are found to be present or absent.

To tell the truth, it is not necessary that every physician should be able to determine with complete scientific accuracy the different species of mosquitoes that may be presented to him; still less is it necessary for him to recognize them in the different stages of egg, larvæ, and nymph, as well as in the adult form. Such determinations can only be made by naturalists who have made a specialty of this work; and here we have the unusual phenomenon of the cabinet entomologist, to whom we must have recourse for the determination

of winged insects gathered in habitations, or of larvæ and nymphæ procured by a fine net from puddles of water, becoming not only a necessary aid but even a counselor and authorized guide of the hygienist and the physician. The matter becomes even still more complicated, for it is useful to examine experimentally, in different species of mosquitoes, the subsequent development of parasitic organisms found in the blood of man or of animals. This leads to the most delicate histological researches and the most difficult experimentation well exemplified by the recent discoveries in filariosis and yellow fever.

About five hundred species of mosquitoes are known. This will give an idea of the unexpected amplitude of the studies that are now being pursued and of the preponderant part that entomology has obtained in them. I should give a very incomplete idea of its importance if I confined myself to what has just been said. Other diptera also attract the attention of parasitologists, because they transmit certain very fatal diseases. Everyone has heard of nagana, the epidemic having a mysterious cause that affects European domestic animals that are taken into certain regions of tropical Africa. Livingstone recognized that it was occasioned by the sting of the tse-tse fly (*Glossina morsitans*), but it was a long time before the actual details of the infection were understood. The problem is now solved. The tse-tse inoculates cattle with a protozoan which it has drawn from the blood of a sick animal; the parasite inoculated in this manner multiplies very rapidly in the blood of its new host and the latter soon presents characteristic symptoms of nagana.

The animalcule in question is a simple flagellate, known under the name of *Trypanosoma brucei*. It swims in the plasma, reproduces itself there by longitudinal division, and the blood thus becomes charged with more numerous parasites day by day. It is duly established that these are the efficient cause of the disease which is almost always fatal. The Trypanosomata are then redoubtable parasites and their history ought to especially interest the physician if it is proved that the human species may also be attacked by similar organisms.

Now the malady of sleeping sickness, which flourishes in tropical Africa with dreadful intensity, so that it devastates very extensive territories, as it has done during recent years on the Kongo and in Uganda, is nothing less than a trypanosomosis. The specific parasite is here the *Trypanosoma gambiense*, that is transmitted by the *Glossina palpalis* and, apparently, by other species of trypanosomata whose agents of transmission are not *Glossinæ* but *Muscidæ* of other types or various *Tabanidæ*. Still further it is known that there exists in Algeria a human trypanosomosis which, in view of the absence of *Glossinæ* in that region, must also be placed in the latter

category. It therefore follows that the assistance of the dipterologist in questions of epidemiology is still more important than we had supposed.

In addition to the above, it should be said that it is not only necessary to establish the nature of pathogenic insects, to ascertain their habits and their metamorphoses, to find the most effective means of destroying them or of driving them away, but also to follow in its most minute details the cycle of the evolution of the parasite in the interior of the organs. Yet all this is only one aspect of the matter, and I may say that it is not the most important one. It is, in fact, indispensable to experiment with the parasite itself, so as to arrest, if possible, its invading march, and to determine the conditions capable of attenuating its pathogenic action and of rendering the organism of its host indifferent to its attacks. A trypanosoma swarms in the blood of the rat without inconveniencing that animal in any appreciable way. Such an endurance is doubtless the result of a progressive and hereditary toleration, which gives reason to suppose that man and the animals that are the present time defenseless as regards the trypanosomata are capable also of acquiring immunity. The investigation of the conditions by which this may be established is surely one of the most important problems of the present day. This leads us back to the ever-present topic of phagocytosis and the pathological physiology of the white corpuscles.

But yesterday unknown in human parasitology, the trypanosomata have to-day acquired an important place in this special department of medicine. It may be said that their importance as well as that of the zoological group to which they belong increases every day.

The Spirochæta, assigned for a long time to the bacteria, are really protozoa, in particular flagellata of a somewhat aberrant type. Two diseases of man are caused by them—recurrent fever and the tick fever of central Africa—these having, respectively, as pathogenic agents the *Spirochætum recurrentis* and the *Spirochætum duttoni*. There are also known several kinds of spirochætosis that affects animals. Now it has been established that these parasitic affections are transmitted by the bite of various kinds of arthropods: Hemiptera, such as the bedbug (*Acanthia lectularia*); and Ixodidæ, such as the *Ornithodorus savignyi*. The most redoubtable of the diseases of man, syphilis, of which Schaudinn has recently found the pathogenic agent (*Treponema pallidum*), is also a kind of spirochætosis, but it is normally transmitted by the contact of mucous membranes that are ulcerated in a manner that is often inappreciable. In this respect it offers a very striking analogy to dourine or mal de coit which, although due to the existence of a trypanosoma (*T. equiperdum*), is propagated in the same way, without the bite of any insect.

Apart from these exceptional cases we see why the Hemiptera and

the Ixodidæ demand the closest attention from physicians. They no longer confine themselves to playing the part of intermittent parasites; they inoculate infectious diseases of incontestable gravity. The scope of our studies enlarges accordingly, and it becomes necessary to know, in all its details, in all its metamorphoses, the biological history of these new enemies, within whose bodies the Spirochæta and the Treponema may undergo transformations whose cycle we must also elucidate.

The Ixodidæ, then, have recently revealed themselves to us as the propagators of dangerous diseases. In reality the parasitologists, who must pay attention to comparative medicine or else restrict their view to a quite narrow horizon, already knew of the pernicious part which these play in the transmission of babesiosis, notably in that form known as "Texas fever." This epizootic decimates the herds of cattle in the southern part of the United States, in the Argentine Republic, and even in certain countries of Europe. It has for its cause a very small, pyriform parasite (*Babesia bovis*), which lives in the red blood corpuscles whose substance it destroys, thus occasioning a characteristic hemoglobinuria. The important observations of Theobald Smith and Kilborne showed that this infectious agent was transmitted to the cattle by the *Rhipicephalus annulatus*, a species of tick of which numerous varieties are widely spread throughout the globe.

Special kinds of babesiosis occur in the dog, the horse, and other mammals. None has yet been determined in man, at least in an indisputable manner, but it may be reasonably affirmed that this parasitic type probably does not spare our species. Decidedly, while awaiting the study of the Gamasidæ and other Acarids, we ought henceforth to give as much attention to the Ixodidæ as to the mosquitoes, the fleas, the Glossinæ, and the Tabanidæ. Medical zoology, that has already conquered such vast territories in the domain of the protozoa, is now annexing a considerable part of that belonging to the arthropods.

The studies which we should pursue are therefore as varied and complex as possible. Among the numerous questions that come up with regard to them there is none that is more stimulating at the present time than the mystery that surrounds certain parasites, whose existence is certain and whose animal nature seems very probable, but which we have never yet been able to discover.

Among this number is the parasite of yellow fever. We know that it is transmitted by a mosquito (*Stegomyia calopus*), which is not infectious until the twelfth day after it has bitten a person affected with yellow fever—that is to say, until the parasite has undergone, in its organism, transformations which are more of less analogous

to those of which the hæmatozoa of malarial fever give us so remarkable an example. In spite of these precise indications every search for the infectious agent has hitherto been in vain, doubtless because it is too small to be discovered by our means of investigation. It is not the only one of which this can be said, for there is every reason to suppose that hæmaturic bilious fever and hydrophobia, among others, belong to that category of parasitic affections whose germ is yet unknown. It may be remarked that the researches of Schaudinn have shown that certain forms of Spirochæta observed in the digestive tube of the mosquito (*Culex pipiens*) are sufficiently small to go through porcelain filters and only become apparent to the strongest magnifying powers when they are assembled in considerable numbers. Optical combinations will doubtless yet be discovered that will permit us to see and study these excessively minute creatures. Their investigation opens a way for researches of a peculiarly delicate and interesting character.

The facts recently acquired, or the questions recently raised in the realm of helminthology, are also not without importance. Hardly twenty-five years ago we saw helminthology restricted to a description, or rather a summary enumeration, of the four or five intestinal worms most widely found in Europe—that is to say, the two tænias, armed and unarmed; the ascaris, the oxyuris, and the tricocephalus. To complete the survey there was also mentioned the filaria of Medina as a sort of exotic curiosity. To show acquaintance with rarities, reference was made to the *Strongylus gigas*. As to the trematodes, we were confined to the great and little liver fluke, and the Bilharzia was, for reason, discreetly alluded to. All this was comprised, in the teaching of our medical faculties, in some three or four lessons. I know something about it, as this was the plan on which I was educated.

Note also that the French faculties and schools of medicine are almost the only ones in the entire world that have a teaching chair of natural history. It is true that the professor must, at the same time, teach both zoology and botany in their applications to medicine, as if it were possible to find, in the present state of scientific progress, men capable of teaching with authority these two branches of natural history that have long been so profoundly differentiated from each other. In practice this difficulty was avoided, since the professor taught that branch with which he was mostly familiar, leaving to an associate the task of teaching the other. Thus it was that my learned predecessor, Professor Baillon, who occupied the chair of medical natural history of the Faculty of Paris for such a long time, and whose botanical works had the greatest reputation, reserved for himself the teaching of botany, his associate had, then, to teach zoology.

As far back as 1883, the date when I had the honor to commence my teaching at the Faculty of Paris, the course of medical zoology was in reality only an elementary course of the Faculty of Sciences. This was by no means wholly bad, as we had to put into shape young people just out of college whose acquaintance with natural history was wholly inadequate; but it was necessary to supplement this elementary course by a detailed study of the parasites of animal origin.

Convinced of the ever-increasing importance in human pathology of the part played by parasites of this nature, a part evidently misunderstood in many cases; instructed by the discovery of new parasites—in the extreme Orient, for example; persuaded that colonial expeditions, then again becoming popular in Europe, would certainly be sure to bring to our notice many new facts relating to this subject, I decided to break away from this defective instruction and to devote almost my entire course of teaching to the study of parasitic diseases. The results were immediate; somewhat disconcerted at first by the novelty of this method of teaching, the students soon realized in full its importance. It is not for me to say whether or not its success was comparable to the effort made, but I believe I have a right to state that this innovation, which amounted to the creation of a new branch of instruction, was required by the necessities of the time. I see a proof of this in the fact that all the faculties and schools of France followed my example and were well pleased with it. The same occurred in some other countries, particularly in Roumania, the Argentine Republic, and in Chile, where chairs of medical natural history were established.

That which I was able to realize in 1883 as associate I was able to complete in 1897 as titular professor. I had the good fortune to assume my chair at the moment when the programme of medical studies had just been modified in a very satisfactory manner. Medical natural history, since that is the title of my course, was henceforth placed in the programme of studies for the third year, which enabled me to discuss more fully the important questions arising from parasitology and to enter into clinical details and minutiæ of physiology and pathological anatomy, which would not have been well comprehended by students of the first year. Hence there results a much greater specialization in the teaching, as well as an entirely new adjustment of the practical and laboratory work. The establishment of the *Archives de Parasitologie*, of which the eleventh volume is finished, is another testimony to the profound reform which I have been able to effect.

It will be understood that, in a course of this kind, natural history must predominate, and that it can not be completely given by a man whose education is exclusively medical. In fact, helminthology no longer remains in the golden age which I described above. What

enormous advances have been made during the past twenty-five years! How many species of parasites have been added to the list which was then so restricted! The complete study of these animals necessitates very technical zoological knowledge; it is not sufficient to determine their structure, to follow their migrations and metamorphoses, to recognize them in their different transformations. To ascertain the lesions which they produce we must also know the parasites of the most various kinds of animals in order to discover the relationship that may exist between those that inhabit man and those found in different species.

Davaine described, from very imperfect specimens, a little tænia coming from the Comorin Islands, to which he gave the name *Tænia madagascarensis*. Cobbold published, under the name of *Distoma ringeri*, a trematode that lives in Japan and China in the lungs of man and which frequently causes hæmoptysis. Who, then, without possessing the knowledge I have just mentioned and which can only be acquired by long practice in zoology, would have suspected that the first of these parasites belongs to a type found only quite exceptionally in mammals and man, but which normally belongs to the Gallinaceæ? Who, then, except under such circumstances, would have recognized in the second one a parasite already discovered by Kerbert in the tiger? Such relations are not merely simple curiosities, as superficial minds might suppose; they are of the highest importance, since they put us on the track of the origin of the parasitic diseases of man, the only ones on the whole that are interesting to the physician. It would be easy to cite other examples illustrating this proposition in an equally clear manner.

From a more strictly medical point of view the Helminthes, or intestinal worms, are about to resume in medicine the part which was in former times attributed to them without contest, but which was taken from them by the progress of bacteriology. The discovery of the pathogenic rôle of microbes caused a surprising progress in the etiology, prophylaxis, and treatment of infectious diseases. By a very comprehensible exaggeration everything was ascribed to bacteria, and it was a great comfort to medicine to find in them an explanation of phenomena that had for centuries obstinately refused to give up their secret. It is far from being my intention to contest the important part which bacteria play in the production of disease, but I am clearly of the opinion that often they are injurious only because they have been preceded in their pernicious work by various Helminthes which have prepared the way for them and enabled them to produce their deleterious effects.

Guiart found that the *Ascaris conocephala* produces in the intestinal mucous membrane of the dolphin quite deep erosions, due to the three powerful nodules with which its mouth is armed; the

Ascaris lumbricoides does the same in man in some degree. Also clinicians have, in fact, often noted, but without attaching to the fact the importance that it merits, the presence of ascarides in greater or less numbers in individuals suffering from intestinal disorders, especially in typhoid fever. Roederer and Wagler, in 1760, observed at Göttingen a violent epidemic of typhoid fever, or, as they called it, *morbus mucosus*, in the course of which they discovered the Tricocephalus. This parasite was found abundantly in the intestines of those persons upon whom they made autopsies.

For some fifteen years past there has been described in medicine, under the name of appendicitis, an affection of the ileo-cæcal region which clinicians considered as a new disease. As attention was called to it about the time that influenza began to flourish, there was no delay in attempting to establish a relationship between these two morbid manifestations, which have, however, no resemblance to each other, and it was at once proclaimed that "appendicitis is the grippe of the large intestine." An admirable formula for those who amuse themselves with the sound of words. A deceptive subterfuge for those who wish explanations based upon well-observed facts.

On March 12, 1901, Metchnikoff was able to demonstrate at the tribune of the Academy of Medicine that appendicitis is caused by the Tricocephalus. His brilliant demonstration was rather coldly received. The surgeons boldly continued to open abdomens and remove appendices. Recently when the question of appendicitis again came up for discussion before the academy, I took part in my turn in order to defend the theory of its verminous origin, supporting it by a number of data and anatomo-physiological facts that was truly imposing.[a] I also showed the antiquity of appendicitis, formerly known under the name of typhlo-colitis. I do not cherish the illusion that I have converted the surgeons to my views, although some of them have informed me that they accept them unreservedly, but I have the right to consider that the verminous origin of appendicitis is definitely established and that it explains the greater part of the clinical phenomena.

Can we then say that the Helminthes are infectious? Not at all; while they undoubtedly play a part in the production of disease, that part is, in a manner, only a preparatory one. The ascaris, as we have seen, erodes and ulcerates the intestinal mucous membrane; the injuries produced there are still more grave when it is attacked by the Tricocephalus, the Uncinaria, and other Helminthes that, armed with hooks or not, pierce it and bury themselves within far enough to reach the capillary blood vessels. They thus produce a series of

[a] R. Blanchard, L'appendicite et la typhlo-colite sont très fréquemment des affections vermineuses. *Archives de Parasitologie*, X, p. 405, 1906.

minute orifices, by means of which the pathogenic microbes which are so frequently encountered as saprophytes in individuals of good health may invade the organism and occasion there an infection. We may authoritatively enunciate this aphorism: There is no intestinal infection without Helminthes to break out a way for the infectious microbes. This alone would suffice to revive our interest in the Helminthes, even if it had not been shown by recent experience in colonial medicine that animal parasites are much more noxious than has generally been supposed; they play, in fact, a principal part in the pathology of hot countries.

I here return to a topic which is particularly dear to me. I am a strong partisan of colonial expansion, and I believe firmly that it can have no safer guide than medicine. Now, the great majority of the diseases of hot countries are caused by parasites, and these parasites are, for the most part, of animal nature. As science is making great progress in this particular domain, and as from one year to another there arise questions that are really unforeseen, it seemed to me necessary to create at Paris, close beside the Faculty of Medicine, a complementary course of instruction rapidly comprehensive in character, by means of which colonial physicians returning to the metropolis could inform themselves fully regarding these new questions. From this idea was born the Institute of Colonial Medicine, which I had the happiness of founding in 1902, thanks to the support of the University of Paris. The persons who take up the courses [a] are, for the most part, physicians who have liven in the Tropics and who are desirous of perfecting themselves in the new methods of investigation. They return thither better armed for scientific research, knowing what are the desiderata of the present moment, capable of pursuing researches that are always delicate, their minds awakened and animated with the most ardent desire to do useful work. There is reason to hope that their efforts will not be in vain and that they will elucidate some of the questions that are yet obscure.

We may say, indeed, that by thus enlarging our scope and extending our studies to exotic pathology we have opened an immense field for medical zoology. A number of other important problems will soon be taken up, among which the toxicology of animal parasites is of primary importance.

We have become familiarized with the idea that bacteria eliminate toxines. Roux and Yersin proved the existence of such and the part which they play in diphtheria. Since this masterly demonstration no

[a] The fifth session was held from October to the end of December, 1905. The institute has issued up to the present time 133 diplomas of colonial medicine of the University of Paris, about half of which went to foreigners, the greater part of these being Spanish-Americans.

one has further doubt but that certain symptoms in infectious diseases are caused by noxious substances eliminated by the microbes. Can such a proposition be made more general? Do Helminthes and other animal parasites produce analogous substances? How active are they, and how far may we attribute to them certain morbid phenomena? Yes; without doubt parasites of an animal nature behave in the same manner as do bacteria, and it is truly surprising that this has not been sooner recognized.[a]

I find a very convincing example of this in malarial fever, the febrile exacerbation being, in my opinion, merely the result of an intoxication of the organism. It may be demonstrated in this way: The hematozoon, which lodges, increases, and multiplies in the interior of a red-blood corpuscle, obeys the common rule—that is to say, it assimilates substances foreign to its own organism, and, at the same time, disassimilates and rejects about it soluble refuse matter. This accumulates in the interior of the globule and is not shed into the current of the blood until the globule bursts. At first it is too much diluted to be active, but its quantity increases, as does the number of parasites, and soon it produces a first febrile condition. It is generally supposed that the fever becomes more and more violent if it is not treated with quinine; that is to say, that the toxines are discharged into the plasma in greater and greater quantities. This example is, I think, sufficiently characteristic; it has at least the merit of being taken from a disease whose course is known to everyone, and, besides, it is the only rational explanation of the febrile phenomena.

In view of this, it is not surprising to find that the trypanosomata also produce toxic substances to which we must attribute some of the symptoms of the sleeping sickness, in particular the somnolence characteristic of that malady. It is already known that the Bothriocephalus sometimes causes progressive pernicious anæmia, not because it occasions an intestinal hæmorrhage, but as a consequence of the absorption of substances which it excretes, and which are voided into the intestine; we suspect that other Helminthes may be similarly effective in a greater or less degree. Here, then, there is opened an entirely new chapter in chemical physiology and we may say that it now appears to be beset with the most serious difficulties.

In bringing these questions before you I do not pretend to have shown all the aspects in which zoology is related to medicine. The union of these two sciences becomes every day more close. Sir Patrick Manson said to me one day, "The time is near at hand when every school of medicine will have a chair of zoology; in France

[a] R. Blanchard, Substances toxiques produites par les parasites animaux. Archives de Parasitologie, X, p. 84, 1905.

you have accomplished this in advance of other countries." This remark of the illustrious English parasitologist was not to remain as a mere empty phrase. Less than two years later the School of Tropical Medicine at London established, in accordance with his recommendation, a chair of protozoology and one of helminthology. This example was soon followed by the School of Tropical Medicine of Liverpool, where there was established a chair of animal parasitology, then by the universities of London and Cambridge, who happily confided to Professors Minchin and Nuttall a new course of instruction relating to the protozoa and their relations to disease.

Thus were surpassed at one stroke the French faculties of medicine, who could only offer in competition with these seasonable and opportune innovations their time-worn instruction in medical natural history. I have already mentioned under what influence this instruction became specialized as regards animal and vegetal parasitology, exclusive of bacteria,[a] but I regret to add that owing to the insufficient funds allowed it has often a merely theoretical character. Now, we have shown what important problems it is urgently necessary to solve and in what direction science ought now to proceed. The researches which are now to be made can not be productive of satisfactory results unless powerful and adequate means are employed. I mean unless sufficiently large sums are furnished. Money is not only the sinews of war; it is still more the sinews of science. Success smiles on those who, abandoning theoretical and abstract speculations, grapple closely with problems and tear from them their secrets.

The schools of tropical medicine of London and Liverpool have during the past five or six years done remarkable work in the field of the parasitology of hot climates, not so much because of the excellent quality of the eminent men who have conducted the new movement, a quality which is certainly incontestable, as because of the considerable subsidies that the generosity of the public has put at their disposal. Other countries have attacked the matter in another way. Germany, for example, has established at the imperial office of public health (*Kaiserliches Gesundheitsamt*) a section of animal parasitology at whose head Doctor Schaudinn was placed and given at once the title of councilor of state. This was a fitting supplement to an institution that has already rendered most signal service, and is a point of departure for further progress. But Schaudinn was not to remain at the imperial office. He soon quitted it for the Naval

[a] By a decree dated December 15, 1906, the chair of medical natural history of the Faculty of Medicine of Paris was transformed into a chair of parasitology and medical natural history. This does not change in any way my functions or my means of action. It is merely a recognition of a state of things that has existed for nearly ten years, and the official sanction of my efforts.

Institute of Medicine at Hamburg, where a premature death awaited him. Parasitology mourns his loss.

The United States, too, having become a colonial power by the conquest of Porto Rico and the Philippines, have established at Washington, as a dependence of the Marine-Hospital Service, a division of medical zoology, of which Dr. Ch. Wardell Stiles is the eminent chief. His past will answer for his future. Under his zealous leadership the new division can not fail to become one of the most active and prolific centers of scientific research.

Such examples might well be followed by all countries that have intertropical colonies. It is, indeed, not sufficient to note the progress of one's neighbor; there should also be assigned to scientific research the sums requisite for it. Let us hope that the countries that have hitherto shown themselves inert or too parsimonious may soon comprehend that it is due to their honor and to their scientific reputation to establish laboratories of the same kind, or at least to endow with a greater liberality those which already exist and which do not lack the will to do good work.

Whatever may happen, it is clear that medical zoology is only at the beginning of its career. Numerous important problems present themselves that demand an immediate solution and the penetration of civilized nations into regions hitherto unexplored or insufficiently known will bring forward a great many others to which parasitology will furnish a solution. After the remarkable success which bacteriology has had we greet with confidence the dawn of the day when medical zoology will obtain its highest development.

THE RÔLE OF CHEMISTRY IN PAINTINGS.[a]

By Eugène Lemaire.

Chemistry respects nothing. Not long ago it invaded a domain which would seem forbidden to it, that of art. To-day it instructs artists how a painting should be made, connoisseurs how it should be bought, and collectors how it should be preserved.

It is true that there have always been painters who, ignorant of chemistry, have yet produced admirable and unalterable works, but they are the exception; and chemists claim that these artists while preparing and trying their colors, mixtures, and varnishes used chemistry, as M. Jourdain used prose, without knowing it.

It is forty years since modern chemistry made its entry into the domain of painting. The Bavarian chemist, Max von Pettenkofer, a professor of chemistry at Munich, living in the midst of the artistic riches of that great city, among artists, an artist himself, had been struck by the ignorance of museum custodians regarding the restoration and rational preservation of paintings, and he resolved to study these questions. He was fortunate enough to establish principles and formulate rules which should be a guide to custodians. To-day these rules are observed in all large museums. A memorable example, among others, will show what it cost one of the richest museums for having transgressed them. The city of Lille, finding its pictures crowded in the city hall, the old palace of Rihour, had constructed at great expense a vast and luxurious palais des beaux-arts, destined to contain its richest collections. Unfortunately, in 1895, three years after the opening, all the pictures were in such a pitiable condition that it was necessary to remove them at once, to lower the ceilings of the immense rooms about 8 feet, to divide them by partitions, and to entirely remodel the system of heating and ventilation.

Before passing to the preservation of a picture, an example will show what aid chemistry can give to the purchaser or the collector.

---

[a] Translated, by permission, from La Nature, Paris, No. 1760, February 16, 1907.

If we cut from an oil painting a small strip about a millimeter wide and a few millimeters long, we do not injure or detract from the value of the painting, especially if the strip be from the edge, but we have a sample sufficient for many microscopic preparations for observing the layers in cross section. All the touches by the painter then appear in parallel bands laid on in chronological order, and from them we learn the nature, composition, and even the age of the several layers. It will thus be easy, knowing the style of the master, to determine whether a date or a signature are apocryphal—that is, whether or not they are between two layers of varnish and whether or not the varnishes are of the same composition.

The chemical questions that have to do with painting have been carefully studied in recent years by a chemist of world-wide reputation, Doctor Ostwald, of Leipzig, who is one of the founders of physical chemistry as well as a talented painter. In collaboration with A. Genthe he at first investigated the question of drying, and showed that the oxidation of linseed oil which accompanies the drying process is not a normal chemical reaction. At first the process of absorption of oxygen proceeds very slowly, then it increases, attains a maximum, diminishes, and finally maintains a constant value almost indefinitely. With a normal reaction this rapidity would immediately assume a very great value, then quickly diminish. It was understood that this divergence was due to the formation, from the products of oxidation of the oil, of a catalytic substance—that is to say, acting apparently by its mere presence, and after the manner of a ferment, to produce reactions. The oxidized substances, with which the linseed oil is left in contact or burned, has no other effect than to give birth more rapidly to that substance, and the drying oil that is added in small quantities to colors to make them dry more quickly contains notable proportions of it.

Other experiments have proved that the autocatalyzation of linseed oil is hastened by light; in other words, that a painting dries more quickly during the day and in the sunlight than during the night and in darkness. It is moreover a fact well known to painters that, other things being equal, the light paints dry more quickly than the dark. This is due to the fact that the black pigment absorbing the light hinders it from hastening the oxidization of the oil. To hasten the drying of a picture it should be put in full sunlight, but if it is to be kept fresh, put it in darkness.

CAUSES OF THE DESTRUCTION OF PAINTINGS.

To make an unalterable and durable painting, one must necessarily know all the possible causes of alteration and destruction. These are

many. They are, first, darkening of oils and varnishes; second, the chemical action of pigments one on another; third, the diversity of action of exterior agents on the layer of paint and on the support.

In the long run all oils and varnishes resinify and turn brown. The picture then becomes covered with a more or less opaque layer, beneath which the original colors, even though remaining pure, appear as if veiled in black It is to this action that the "museum tone" of almost all old paintings is due. Frescoes are naturally exempt from it. *Le Jugement dernier*, by Michael Angelo, in the Sistine Chapel of the Vatican is no exception to this rule; its darkening is of exterior origin; it is due to the incense arising from the alter which was formerly placed before this fresco. As this browning or darkening is due to the oxidization of oil, Doctor Ostwald recommends, to prevent this action, that the paintings be sealed between two pieces of glass cemented at the edges.

All painters know to-day the disastrous effect which is produced in the end by the use of a color which has a lead base (white lead, for example) when mixed with another color containing sulphur, such as vermilion or cadmium yellow. By double decomposition the lead ultimately returns to its most stable form—that of the black sulphide, because the elements of that transformation have been furnished to it. Confined air, which always contains a little hydrogen sulphate, produces, moreover, this same blackening of all colors with a lead base.

It is to these kinds of reactions that must be attributed "les repentirs," apparitions in the light parts of a painting, of subjects which were afterwards covered over and form there a subjacent layer.

To avoid the difficulties of mixing, which are always to be feared, some painters prefer to obtain the effect of the fusion of colors by their juxtaposition with light touches. Near at hand the effect is often deplorable, but at a distance it is always very good if the painter has a profound knowledge of the laws of optics. This explains how that method, yet little understood, is much superior to the other from a technical point of view, but it does not lend itself easily to all kinds of painting.

The early painters knew the greater part of these actions, at least in their effects, and took account of them. It is to them that we owe the effects of *chiaroscuro*, the triumph of Rembrandt. Some people believe that Rembrandt painted with a vivacity of color to shame our most hardy impressionists, but he put on his finished picture a mixture called "Rembrandt sauce," which had the effect of darkening all the tones. If we banish lead, we must also banish the use of litharge for making a drying oil, for it always leaves some traces in

the oil; it is even possible that to these traces may be due the darkening of varnishes, the "museum tone" of which we have already spoken. We have recourse, then, to driers of manganese base, which to-day leaves nothing to be desired.

We have sought to replace white lead—a poison, as are all lead compounds—by zinc white, ZnO, which, while forming compounds with sulphur, does not blacken, for zinc sulphide, ZnS, is white. Unfortunately, zinc white does not spread as well as white lead; at equal weight of pigment it will cause to disappear, even quicker than white lead, a subjacent painting; but this same weight ought, then, to be applied in a greater number of layers, for zinc white does not mix well with oil. This is a great difficulty. Fixed white or sulphate of barium, SO_4Ba, absolutely unalterable, has not given the best results. It was then that "lethophone" was discovered.

Lethophone is a mixture of sulphide of zinc and sulphate of barium, both white substances, which are formed when we make solutions of sulphide of barium and sulphate of zinc. $BaS+SO_4Zn=ZnS+SO_4Ba$.

Unfortunately, though the sulphide of zinc and the sulphate of barium taken alone are absolutely unalterable prepared in this manner, and without one knowing why, they give a mixture which darkens in the light. It is true that the whiteness returns after the lethophone has been placed in darkness. This curious property was none the less an obstacle in its employment. This obstacle no longer exists, for Doctor Ostwald has found the means of avoiding the darkening and guarantees the absolute whiteness of the painting in lethophone should it be exposed three hundred years in full sunlight. This is, it seems, the maximum length of time for which the best of colors are guaranteed.

All these alterations are serious, but they are not definite or without remedy, for, strictly speaking, treating the pictures carefully with hydrogen peroxide, they can be whitened. Another serious thing is the cause which produces the cracking and which is due to the diversity of the nature of the layer of paint and its support.

This support is generally a canvas, which contracts under the effect of dampness and cold, while the layer of paint, on the contrary, expands under the same conditions. When the layer of paint is thin, it maintains a certain elasticity and lends itself to the changes of dimensions, which the variations in temperature and humidity produce; if it is too thick, it breaks. To quote Doctor Ostwald: "The durability of a picture is inversely proportional to the thickness of the layer of color."

All the old paintings that have come down to us without cracking were made very thin. This was the style of the early painters, as

EXAMPLE OF FISSURE IN A FRESCO.

Michael Angelo: *The Creation of Man*, in the Sistine Chapel.

EXAMPLE OF CRACKS IN A PAINTING ON CANVAS.

Rembrandt: *La fille à l'œillet*, in the Dresden Museum. In the upper left-hand corner the cracks are shown on a larger scale.

Van Eyck and Ghirlandajo. It was also of Raphael and his pupils; his Sistine Madonna, at Dresden, bears the date 1515, and is without any cracking. In the same good condition is the portrait of Charles I, and especially the *Portrait of an Unknown Man*, by Vandyke, which are in the Louvre. The state of preservation of some of Rubens paintings in the Louvre is almost as perfect.

In a great number of these paintings the layer of paint is so thin that one can almost always see the texture of the canvas under the color.

Our modern painters are much less careful than the old masters, and may be said to destroy their own works. If it is consoling to think that all that we see at each new salon will not pass on to posterity, it is none the less regrettable to count Ingres among those whose work must disappear. His *Triomphe de Cherubini*, in the Louvre, which is dated 1842, is in a lamentable state, in spite of the very skillful restorations that have been made on it. Although a great admirer of Raphael, Ingres did not imitate his technique, and he has left us only one picture painted well and having some chance of living; happily it is *la Source.*

It is easier to give oneself up to inspiration and to work feverishly, as one actually does, than to paint finely, as was formerly done; but in painting, as in sculpture, or in engraving, the artist ought to be a master of his tools and in full possession of all his powers at every moment; in a word, he should be a man of his trade.

There is, however, a process that is not disposed to cracking; it is that of pastel. Here the color is already divided into granulations and does not form an uninterrupted layer when it is laid on. Unfortunately, the pastel, although well established to-day, does not lend itself to the same effects as painting in oil. The painter Raphael sought to unite the advantages of the two processes some years ago by inventing oil colors solidified in sticks, which could be employed as pastel. These colors were taken from the scrapings or essence, and the paintings had to be varnished as ordinarily. It does not seem to have had great success, and this is very probably because it is suited to only one style—the style of Raphael.

There remains a last solution—that of a rigid support; but is there such a thing? No support is perfect, but hard wood, well seasoned, gives much better results than canvas. It has, however, the inconvenience of limited dimensions and is expensive. A support which has perhaps not been sufficiently considered is sheet metal. It is difficult to judge by experience of the quality of such a support for no very old paintings exist on metal; metal was formerly a very costly product, for the reason that, used as a support, it would have to be very homogeneous and of sufficiently great dimensions. It may

be understood by examining *la Madeleine* of Reni, which has been in the Louvre over four hundred years, that this solution is an excellent one when all the other necessary precautions are taken. This little painting, 15 by 20 inches, is on sheet iron; its colors have kept all their freshness, and it does not show the least trace of cracking. The painting looks almost like an enamel, and has followed without any deterioration all the deformations of the metal, which is, however, greatly crinkled.

Thanks to the notable progress which metallurgy has made in these later years, one can secure to-day, and at a very fair price, thin sheets of iron of many square meters of surface which seem to answer almost all the needs of painters. The metal suffers insignificant modifications in the manner of manufacture so that they constitute almost perfect supports; in any case neither more or less heavy than the present large frame and just as easily handled.

OILS, VARNISHES, AND MEDIUMS USED IN THE PAINTING OF PICTURES.[a]

By A. P. Laurie, M. A., D. Sc.,
Principal of the Heriot-Watt College, Edinburgh.

While in the past various mixtures were used by artists for painting, some of which are only obscurely understood, the necessary mediums for modern painting are comparatively few.

The old painting in beeswax, which has proved remarkably durable, is no longer practiced, and tempera painting with an egg medium is only used now and then. There are in this connection certain unsolved problems, such as the real nature of the medium used by Van Eyck and his immediate successors, which are of historical interest, but which I do not propose to discuss here. The medium in which the pigments are mixed must be closely related to the technique adopted by the painters of the day, and it is not at all probable that the medium used by Van Eyck, while united to his technique, would be of the slightest practical use to the modern painter. An artist's medium, then, has to serve more than one purpose. It must attach the pigment to the paper or canvas on which the picture is painted; it must facilitate the use of the pigment by the artist, and it must bring out all the qualities of translucency, and so on, which the pigment possesses. It should also, as far as possible, protect the pigment from change and injury, either mechanical or chemical. The simplest example of such a medium is the mixture of gum arabic and water used in water-color paintings. The gum arabic serves to attach the pigments to the paper, while the water gives the necessary facility to the pigment under the brush, and the qualities of the pigment are developed by thicker or thinner washes on the white paper background. Such a medium, however, does nothing to protect the pigments used from change and has a limited though beautiful range of expression.

Painting in oil is practically the only other method used by the present-day artist, and it is to painting in oil that this discussion will be devoted.

---

[a] Reprinted, by permission, from Journal of the Society of Arts, London, No. 2837, Vol. LV, Friday, April 5, 1907.

In selecting an oil as suitable for artists' purposes it is necessary to choose what is known as a "drying oil." If, for instance, pigments are ground in olive oil the surface would never dry, and it is therefore useless for the purpose. There are certain vegetable oils which have this property of drying and which are therefore suitable for artists' purposes. I shall only refer to three here—linseed oil, poppy oil, and walnut oil. There is no need to trouble you with the chemical composition of these drying oils, but it is important that the nature of this drying process should be clearly understood. These oils do not dry in the ordinary sense of the term at all. They undergo a process of oxidation when exposed to the air, which converts them from a liquid condition into a tough elastic solid, a solid which slowly undergoes further oxidation, becoming brittle, hard, and resinous. It is then to this process of oxidation that their peculiar properties are due.

These oils are obtained from the seeds or nuts and are present in those bodies as part of the reservoir of food supply for the young embryo of the future plant.

The oil from linseed is obtained by crushing, grinding, and pressure, and in order to increase the yield the ground mass is heated as well as pressed, thus obtaining what is known as a hot-pressed oil, which is subjected to various processes of refining and bleaching. Personally, while regarding such an oil as quite suitable for house painting, I doubt very much the wisdom of using it for artists' purposes. The hot pressing results in the presence of many impurities, which are removed by the addition of sulphuric acid. The chemistry of the whole subject of painters' vehicles is so obscure that it is as well to cling to tradition where possible.

The linseed oil of the earlier centuries was cold-pressed linseed and was refined and bleached by the simple process of exposure to air and sunlight over water. These methods yield a beautiful oil and should be adhered to for artists' purposes.

Poppy oil is obtained from the seeds of the opium poppy (*Papaver somniferum*) by crushing and pressing or by other means of extraction and is easily bleached. It is often used for grinding with whites or delicate blues. It dries more slowly than linseed oil, but has the advantage of being almost colorless.

Walnut oil is obtained from the common walnut (*Juglans regia*) by allowing the nuts to decompose partially and then pressing, and can be obtained almost colorless. It was largely used by the early Italian painters as a drying oil. There are other drying oils, but they are not of special interest to artists.

Having briefly discussed the three drying oils commonly used for artists' purposes, we now go on to consider some of the other vehicles and mediums. The pigment having been ground stiffly in oil is sup-

plied to the artist, who may thus dilute or mix it further, and we shall proceed to consider the materials he may use.

In the first place, he may merely add a little more of one of the oils already referred to. In case, however, that he wishes his picture to dry faster, he may use as a medium instead of raw oil, boiled or drying oil.

The property of the boiled oils depends upon the fact that if, for instance, linseed oil is heated for some time with certain compounds, more usually either compounds of lead, such as lead oxides or lead acetates, or compounds of manganese, such as manganese borate or resinate, it becomes partially oxidized, and if painted out on a surface will "dry" much more quickly.

Of the two methods of preparing drying oils described above, the use of manganese is, I think, preferable, and for this reason: A certain amount of the substances used dissolves in the oil, and consequently an oil prepared with lead dryers contains lead in solution and is very easily darkened by impure air containing sulphur compounds, such as sulphuretted hydrogen. It is therefore probably better to keep such oils out of modern pictures which are exposed to the impure air of cities.

Besides diluting with oil, the artist may prefer to dilute with a medium which will evaporate and leave the layer of oil originally present behind. The mediums most commonly used for this purpose are either turpentine or petroleum. Turpentine, which is obtained by distilling the natural gums of the various pines, is a very suitable medium, as it not only evaporates easily, but also assists in the oxidation of the oil. It has been objected to turpentine that it does not evaporate clean, but always leaves a slight resinous residue behind. This is quite true, but the amount of this residue is very small, and, as far as my experience goes, it gets fairly hard in time, so that there is probably no objection to its use on this ground.

The petroleum oils have the advantage when properly rectified of evaporating quite clean and leaving no residue. I have said when properly rectified. It is important before using such a medium to moisten a piece of blotting paper with it and expose it to the air for a short time. If properly rectified, the petroleum evaporates completely, leaving no greasy stain behind.

Artists sometimes forget the real property of these mediums and then complain afterwards that the pigment does not adhere properly to the surface of the picture. The amount of oil used for grinding different pigments varies very considerably. If the ground is slightly absorbent and the pigment stiffly ground and diluted by the artist with petroleum, the oil in the pigment dissolves in the petroleum and passes freely into the absorbent ground, leaving the pigment when the petroleum has evaporated without sufficient oil to

bind it to the canvas. This may happen with one pigment, but not with another, if in the original grinding more oil has been necessary to get a good consistency.

Having now dealt with the more important diluting mediums, we will consider next the question of varnishes. A very large variety of gums or resins are now available for varnish making, but the number used for artists' purposes is not great.

Varnishes may be conveniently grouped into two divisions—the one called spirit varnishes and the other oil varnishes. The spirit varnishes are prepared from the softer and more soluble gums by dissolving them in some medium which will evaporate and leave a layer of pure resin behind, such as turpentine, alcohol, or petroleum. The varnish artists are most familiar with is prepared by dissolving gum mastic in turpentine. By evaporating, a layer of mastic is left behind. Shellac is usually dissolved in alcohol, and there are also petroleum varnishes in use.

Such spirit varnishes are brittle, weak, and easily dissolved or removed. They should therefore form no part of the body of a picture, but may be used to varnish a completed picture when thoroughly hard, mostly as a protective transparent coating, which can be easily removed without injuring the painting beneath. Mastic varnish, for instance, can be removed by lightly rubbing with the tips of the fingers, the powder of the resin largely assisting. They are apt to bloom, in which case the bloom can be removed by a damp cloth, and some hold that they tend to crack the picture beneath; I have found no proof of this, however.

We next come to the oil varnishes. Oil varnishes are or should be made of the harder gums which will not dissolve freely in turpentine or alcohol. To make an oil varnish the gum is fused and the hot oil added, and the whole heated until a drop placed to cool in a glass plate cools clear. It is then diluted with turpentine. To prevent too slow drying a drying oil may be used, or driers added, and heated with the varnish. While thus the fundamental process is simple, in practice great technical skill is required. But again, either manganese or lead driers can be used, and I advise for artists' use manganese driers, although the varnishes so prepared do not in my experience dry so quickly. The number of gums available, their means of supply, names, and properties form a large and confusing subject, especially as no fixed and clear nomenclature has been arrived at.

For artists' purposes a hard gum should be utilized, such as Zanzibar or Sierra Leone copal, or the hard kauri gum from New Zealand. Carefully selected pieces, light in color, should then be carefully fused and incorporated with pure linseed oil. Amber is a very hard gum of high melting point. The main trouble in using it is the

difficulty of preventing it from getting too dark on fusing. This can be overcome, but in so far as I have been able to test its properties it has no advantage over the kauri resins or copals. These, then, are the principal mediums in everyday use for painting oil pictures. I have excluded all special fancy mediums, as I do not know their composition. They may be quite harmless, but I object to them as a doctor objects to a patent medicine. An artist, if he is wise, will only use such mediums as are of known composition and have stood the test of time and experience.

We shall next, then, proceed to consider various problems which arise in connection with these mediums, and which I may frankly say are far from being solved.

In the first place, then, how far do pigments act chemically on each other when mixed in an oil vehicle? To take a typical example: Will a mixture of white lead, which is so sensitive to sulphur compounds, turn black when mixed with vermillion (sulphide of mercury) or with cadmium yellow (sulphide of cadmium)? It is sometimes stated in the text-books that these pigments must not be mixed together, but all practical experience is against this view, and when we examine a pigment ground in oil under the microscope and notice how the particles are each protected by a layer of oil it is difficult to see how, unless the pigment is soluble in the oil, any action can take place. There is one well-known case when such action does take place, the turning brown of a green made with emerald green and cadmium yellow, but this, I take it, is due to emerald green dissolving slightly in the linseed oil. I once made an experiment which I think is of interest in this connection. I rubbed out some cadmium yellow ground in oil on a glass plate, allowed it to dry, and then coated it with a layer of linseed oil, allowed this to dry and then coated this with emerald green in oil. At the end of six months the combination had turned brown and a section under the microscope revealed the fact that the top layer of cadmium yellow had turned black. This must have been due to the solution of the copper in the emerald green in the linseed oil and the slow diffusion of the copper salt molecules through the solid oil, with formation of black copper sulphide. It is evident then that pigments soluble in linseed oil will slowly diffuse through the solid oil and attack other pigments, but if they are insoluble no change seems to take place.

The next question is, How far does the oil protect pigments from external influences—air, moisture, and injurious gases? I read many years ago a paper dealing with this subject at the Society of Arts,[a] Ignited sulphate of copper is a white opaque powder which is in-

[a] Journal, Vol. XXXIX, 1891, p. 392.

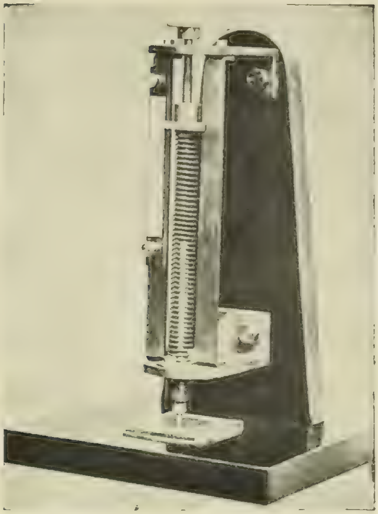
tensely hygroscopic, and in attracting moisture forms a transparent green hydrate. If, then, it is ground up with various media, which are allowed to dry in dry air and then exposed to moist air, the white opaque enamel will become green and transparent if moisture penetrates. One result was to show that while pure resins dissolved in turpentine formed moist-tight surfaces, oils and oil varnishes were all quickly permeable.

The same is true of other gases. Sulphuretted hydrogen quickly blackens white lead in oil through even an oil varnish, but if the white is ground in Canada balsam and then varnished with Canada balsam the white is protected. Verdigris forms a permanent green in such a medium. It does not, however, stop, though it checks the fading of crimson lake, showing that there is probably some decomposition of this color in sunlight apart from air and moisture.

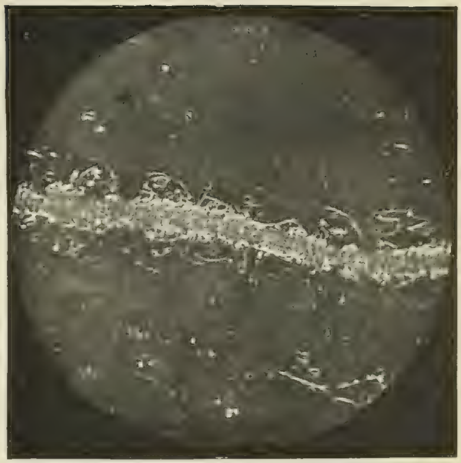
It is evident, then, that while a freer range can be allowed to the oil color than to the water color palette it is safer to select pigments which are permanent in themselves, and not to trust to their protection by the oil from change.

The next question to be considered is the durability of the oil and varnish surfaces themselves. This has not received very much investigation as far as I am aware. I have been recently making experiments with a view to getting some comparative test for the combined toughness and hardness of a varnish. The method is to place the varnish painted out on a glass plate, and dry, under a blunt steel point, the pressure of which on the varnish can be increased by known amounts with a spiral spring.

The varnish is then drawn under the point, and the pressure is increased until the varnish shows a clear definite scratch. Under this test the brittle spirit varnishes break down at a pressure of 100 grams on a steel point of 1 millimeter radius, oil varnishes made from soft gums at from 300 to 500 grams, and oil varnishes made from hard gums at from 900 to 1,200 grams. Moreover, the character of the scratch is very different. Varnishes with an excess of resin in them, and therefore made from soft, easily dissolved gums, give a splintery scratch, while the tough oil varnishes, made from hard gums, give a tear. On exposure to weather during winter the varnishes are all soon reduced to a brittle surface which scratches at 100 grams. In summer, however, they are improved by exposure. This clearly indicates that frost has probably much to do with this, and it is worthy of further investigation. It is easy by this machine to pick out a good varnish for the artist to use as a medium, and if this is done, no doubt the life of the picture, if kept under proper conditions, will be very much increased.



1. Varnish testing machine.



2. Microphotograph of scratch through cheap resinous varnish, showing conchoidal fracture.

3. Microphotograph of crack in picture, showing cracked upper layer (dark), and uninjured lower layer (light).

4. Microphotograph of section through cracked picture.

VARNISH TESTING AND MICROPHOTOGRAPHY OF CRACKED PICTURES.

The next question to be considered is the occasional and capricious cracking of pictures. The explanation of this has, I confess, so far completely baffled me, but there are certain matters of interest in connection with it worth mentioning.

The great difficulty I have found in investigating this matter is due to the fact that I have been unable, under any condition, to produce cracking. The first experiment I tried was more than twelve years ago, when I painted out two, three, and four coats, following each other quickly as soon as the last coat was sufficiently dry on the surface, of flake white (1) ground stiff with oil, (2) diluted with more oil, (3) diluted with copal varnish and (4) diluted with petroleum.

The same set of experiments were repeated with lead sulphate and zinc oxide paint, and with pure zinc oxide, thus making in all 48 different panels representing the different conditions. They are all perfect and show no signs of disintegration to-day. I have also tried painting on ordinary primed canvas with yellow ocher, and then as soon as it was sufficiently dry, laying over it strips of umber, a quick-drying pigment—result, no cracks.

I have also tried the following combinations: Undermost oil paint + mastic or pure mastic, second coat oil paint, third coat oil paint + mastic, umber + mastic, then yellow ocher, then mastic varnish, oil paint + olive oil, umber in oil on top, mastic on top, shellac varnish on top, and other similar combinations. All were hurried, no proper time for drying was allowed, and after twelve months they were free from cracks.

In no instance did any crack, with the exception of the shellac varnish, on the paint mixed with olive oil. I noticed, however, one curious result, the yellow ocher on the top of mastic varnish cracked while still wet, owing to surface tension effects, but changed no more after it was dry.

These experiments, then, were all negative in their results, and certainly eliminate many of the causes to which cracking is supposed to be due.

I had the good fortune to be presented with two pictures which had cracked badly within a few months of painting. In the first picture mastic had been used as a medium, and the cracking was confined to the parts where thin liquid painting had been done and mastic probably freely used, as the surface here was hard and brittle. The canvas was of very poor quality, hardly closer in mesh than coarse muslin. A section through a crack when placed under the microscope showed the crack to be merely through the upper painting, and to be a broad crack with straight edges perpendicular to

the painting surface. The priming had not cracked, but seemed to be drawn out under the crack.

The second picture was painted on a closely woven canvas which had been lightly sized and thinly primed by the artist with a mixture of pigments and linseed oil. The cracking was confined to the white masses of hard dry paint in the sky. A section showed that these cracks also formed broad cracks with perpendicular edges without injury to the undercoating of paint. The undercoating of paint did not, however, seem to be properly attached to the canvas, a layer of spongy, disintegrated material apparently having formed in some way. This condition of things prevailed all over the canvas and suggested that, owing to some disintegration between the canvas and the lower coats of paint, the coats of paint had been stretched, resulting in cracking of the upper coat where it was not elastic enough to yield. In order to get some light on the possible causes of cracking, I determined to measure the actual movements taking place in the canvas itself under different conditions. For this purpose I attached a strip of sized canvas by one end to a glass cylinder and weighted the other end so as to keep it taut over the cylinder. A platinum wire was firmly sewn to the canvas across and projecting out each side, and two little glass rods attached to the glass as indicators. The length of the canvas from the attached end to the platinum wire was 2 centimeters. By measuring the distance between the glass rod and the platinum wire it was possible to measure any expansions or contractions of the canvas itself.

By measuring at both ends and taking a mean any twisting of the canvas was eliminated. On first measuring, the average distance between the glass rod and the platinum wire was 0.45 millimeter. The cylinder was then inclosed for twenty hours over strong sulphuric acid so as to dry the canvas thoroughly. The distance had now increased to 0.55 millimeter, showing a contraction of the canvas on drying. It was now kept for twenty hours in an atmosphere saturated with water vapor.

At the end of this time the readings showed a distance of 0.28 millimeter, showing a total expansion from dry to moist air conditions of 0.27 millimeter. On again replacing over strong sulphuric acid the distance increased to 0.57 millimeter, showing a change in length of 0.29 millimeter, or, taking the mean, of 0.28 millimeter.

The canvas was now painted thickly with yellow ocher and put back in the sulphuric acid and allowed to dry. After one day the distance between the points was 0.54 millimeter, and after thirteen days, when the paint was fairly dry, it was 0.577 millimeter, showing very slight changes in length during the drying of the paint. After

twenty days the distance between points was 0.57 millimeter. On now putting into saturated water vapor, the distance between the points became 0.36 millimeter instead of 0.28 millimeter, showing a distinct and definite contraction on the original canvas.

A coat of umber was now laid on the ocher and allowed to dry in saturated air. In three days the umber was dry, and the distance between points was 0.34 millimeter. On now putting back in dry air a further slight contraction took place, the distance between the points becoming 0.66 millimeter.

A coat of yellow ocher was now put on and left over sulphuric acid; at the end of seven days the reading was 0.73 millimeter, and at the end of a fortnight 0.72.

These figures are a little difficult to follow, but leaving out small fluctuations they bring out the following facts very clearly:

In the first place, the total expansion, from dry to moist air, of the canvas tested, was 0.28 millimeter for 2 centimeters length, or for 1 centimeter (that is, 10 millimeters) it was 1.4 per cent. In the second place, the drying of the thin layers of paint produced a total contraction of the canvas amounting to about 0.16 millimeter. This contraction did not necessarily show itself while the paint was drying under fixed atmospheric conditions, but as soon as the canvas was set moving by change in atmospheric conditions, it asserted itself.

FIG. 1.—APPARATUS FOR MEASURING EXPANSION AND CONTRACTION OF CANVAS.

It is of interest to compare the magnitude of these movements with those required to produce a badly cracked picture.

The cracks in the picture mentioned above varied in diameter from 0.12 to 0.3 millimeter, roughly averaging 0.2 millimeter, and measurements in different directions showed an average of about twelve cracks to 10 centimeters=0.24 millimeter per centimeter, or about double the total expansion of the canvas, as tested.

After nine months the strip of canvas painted as above described was alternately put over sulphuric acid and over water some two or three times, expanding and contracting freely, but without cracking the paint. Another possible source of mischief had to be investigated, and that was the freezing of a damp canvas. Two pictures were taken, one a canvas which had been primed twelve months before with sulphate of lead and zinc oxide, the other a portion of canvas

previously described, which had twelve months before been coated with yellow ocher and then, when only just dry on the surface, coated with umber. After twenty-four hours in saturated air they were kept some four or five hours in a freezing mixture. No cracks developed, and sections showed all coats firmly adhering.

While, then, the result of the experiments has failed to reveal the cause of cracking in the pictures examined, considerable negative evidence has been accumulated which should give us confidence in modern methods of painting. Cracking seems to be due to an expansion of the under layers (possibly due to the action of moisture and frost), which shows in cracks when the top coat is hard either from excess of pigment or from the presence of a medium like mastic.

On the other hand, a sound canvas, properly sized and primed and painted with pure oil and good oil varnishes, with the exclusion of fugitive pigments, seems to withstand very severe treatment without appreciable injury.

There is also very little evidence to confirm the usual statements about expanding surfaces when the paint is drying under normal conditions.

NATIONAL RECLAMATION OF ARID LANDS.

By C. J. Blanchard,
Statistician, United States Reclamation Service.

The year just closed was marked by substantial progress in the work of national reclamation of arid lands. Important structures have been completed, several of the largest engineering works ever attempted in this country are under construction, and detailed plans have been prepared and approved for other works of similar magnitude. The preliminary surveys and examinations, which involved much time and labor, are practically concluded. Out of nearly one hundred projects examined all but twenty-eight have been eliminated for the present, and during the next three years the engineers will concentrate their entire attention upon the building of these great works.

A list of the projects upon which actual construction is now in progress is shown in the table herewith.

Reclamation projects now in process of construction.

Project.	Estimated cost.	Irrigable acreage.
Salt River, Arizona	$5,300,000	200,000
Yuma, California-Arizona	3,500,000	100,000
Uncompahgre, Colorado	5,200,000	150,000
Minidoka, Idaho	1,800,000	80,000
Payette-Boise, Idaho	1,605,000	120,000
Garden City, Kansas	260,000	8,000
Milk River, Montana	1,500,000	40,000
Huntley, Montana	900,000	33,000
Sun River, Montana	500,000	16,000
North Platte, Nebraska-Wyoming	4,100,000	110,000
Truckee-Carson, Nevada	4,000,000	200,000
Hondo, New Mexico	336,000	10,000
Carlsbad, New Mexico	600,000	20,000
Rio Grande, New Mexico	200,000	15,000
Lower Yellowstone, Montana-North Dakota	2,700,000	60,000
Buford-Trenton, Williston, Nesson, North Dakota	1,270,000	40,000
Klamath, Oregon-California	2,400,000	50,000
Umatilla, Oregon	1,100,000	18,000
Belle Fourche, South Dakota	3,000,000	100,000
Strawberry Valley, Utah	1,850,000	35,000
Okanogan, Washington	500,000	9,000
Tieton, Washington	1,400,000	24,000
Sunnyside, Washington	2,000,000	40,000
Wapeto, Washington	600,000	20,000
Shoshone, Wyoming	3,500,000	100,000
Total	50,121,000	1,598,000

The reclamation fund.—The receipts from the sales of public lands up to and including the fiscal year ended June 30, 1906, are shown in the following table:

State or Territory.	Increment to fund during fiscal year ending June 30, 1906.	Total reclamation fund to June 30, 1906.	State or Territory.	Increment to fund during fiscal year ending June 30, 1906.	Total reclamation fund to June 30, 1906.
Arizona	$54,559.06	$298,327.25	North Dakota	$933,012.96	$5,373,604.90
California	239,320.01	2,562,377.70	Oklahoma	514,325.73	3,642,029.10
Colorado	34,068.16	2,503,802.05	Oregon	491,069.48	5,260,449.82
Idaho [a]	315,175.56	2,349,875.08	South Dakota	279,300.55	1,302,472.68
Kansas	75,370.50	215,215.19	Utah	114,595.02	476,671.41
Montana	486,637.10	2,633,324.55	Washington	489,958.56	3,541,391.57
Nebraska	74,704.24	746,553.81	Wyoming	326,380.47	1,512,181.89
Nevada	35,843.13	100,772.25	Total	5,166,336.50	33,242,444.52
New Mexico	202,015.97	723,365.27			

[a] Receipts from town-lot sales in Idaho, $60,160 since June 30, 1906.

The estimated increment to the fund for the years 1907 and 1908 is $8,338,139.63, making a total of $41,580,584.15, which will be available for irrigation work during those years.

The allotments now made in the various States and Territories are as follows:

Arizona: Salt River		$4,539,161
California-Arizona: Yuma		3,000,000
California: Orland		650,000
Colorado: Uncompahgre		2,900,000
Idaho:		
Minidoka	$1,675,000	
Payette-Boise	1,490,000	
		3,165,000
Kansas: Garden City		260,000
Montana:		
St. Mary	1,000,000	
Huntley	900,000	
Sun River	500,000	
Lower Yellowstone	1,800,000	
		4,200,000
Nebraska-Wyoming: North Platte		3,330,000
Nevada: Truckee-Carson		3,700,000
New Mexico:		
Hondo	360,000	
Carlsbad	600,000	
Leasburg Diversion	200,000	
		1,160,000
North Dakota:		
Lower Yellowstone	900,000	
Buford-Trenton	300,000	
Williston	400,000	
Nesson	300,000	
		1,900,000

SALT RIVER PROJECT, ARIZONA.

View of completed through cut on high line wagon road directly above east wall of Salt River dam site.

LAYING FOUNDATION OF ROOSEVELT DAM.

Foundation covers more than an acre of ground.

Oregon:		
Klamath	$2,000,000	
Umatilla	1,000,000	
		$3,000,000
South Dakota: Belle Fourche		2,100,000
Utah: Strawberry Valley		1,250,000
Washington:		
Okanogan	500,000	
Tieton	1,250,000	
Sunnyside	1,100,000	
Wapato	100,000	
		2,950,000
Wyoming: Shoshone		2,250,000
Total		40,354,161

ARIZONA.

Salt River project.—In the order of magnitude and prominence of its engineering features the Salt River project ranks first. Actual construction has been going on since April, 1904, and on September 20, 1906, the first stone was laid in the great Roosevelt dam.

This structure when completed will be one of the highest dams in the world. It will be of uncoursed rubble masonry (sandstone and cement), with arch upstream. It will be 800 feet long on top, 235 feet at river bed, and 286 feet above the lowest foundations. It will be finished in 1908 and will create one of the largest artificial lakes in the world. The lake will contain 1,400,000 acre-feet, or sufficient water to cover that many acres 1 foot deep. Its capacity is fourteen times greater than the Croton reservoir, and it will store more water than the Assuan dam in Egypt. The location of the dam site is 62 miles above Phoenix, at a point just below the junction of Salt River and its tributary, Tonto Creek.

Owing to the inaccessible location of the site the preliminary work was arduous and expensive. It was necessary to construct a highway for more than 40 miles through an exceedingly broken and rugged country. A large part of the distance is in canyons, and for miles the road is literally hewn out of the solid rock. In many places it hugs precipices 1,000 feet high. The municipalities of Phoenix, Mesa, and Tempe, in order to become supply points for the army of laborers which would be employed continuously on the work during the construction period of four years, contributed $75,000 to defray a part of the cost of the road work. All of this work was done by the Government and not by contract, and a rather interesting feature was the employment of a large number of Apache, Pima, Papago, and Maricopa Indians as day laborers. The experiment was eminently successful, as the Indians proved industrious and faithful, and were especially useful with pick and shovel.

In the construction of the dam 240,000 barrels of cement are required. The cost of cement delivered at the dam site by any private agency would have been almost prohibitive. Owing to a fortunate discovery near the dam site of the materials required for its manufacture, it was decided to erect a mill and furnish cement to the contractor. This mill began operation in April, 1905, and is turning out first-class cement at a cost which will save the farmers over $1,000,000 on the first bid submitted by the manufacturers.

A power canal 17 miles long has been constructed to the top of the hill at the dam site, where the water drops through a tunnel sheer 220 feet upon great turbines. Here electricity is generated for all purposes. It furnishes the contractor his power; it runs the cement mill, the rock crusher, and the pumps; it lights the camp, the city of Roosevelt, and illuminates the canyon throughout the night.

During the early progress of the work the Government operated two sawmills in the forest reserves nearby, and cut many millions of feet of lumber for use in timbering tunnels, for concrete forms, for buildings, repairs, bridges, etc.

In the lower end of the reservoir, on a flat just above the river, is located the thriving little city of Roosevelt, a city of 2,000 people, with waterworks, electric lights, schools, stores, etc. When the dam is completed the site of this town will be submerged 200 feet.

Work on the dam has been greatly delayed by reason of several unprecedented floods, which have swept away the false works and carried away some of the machinery of the contractor. The Salt River project will cost $6,500,000, will irrigate about 200,000 acres of land, and will be completed in 1909.

NEVADA.

Truckee-Carson project.—On June 17, 1905, the third anniversary of the reclamation act, occurred the formal opening of the first completed work of the Reclamation Service. In the presence of a distinguished body of Congressmen, governors, legislators, engineers, and others the gates in the Truckee dam were shut down, the headgates of the great canal were opened, and the waters of the Truckee River for the first time were turned into the Carson River reservoir, from whence long lines of canals and ditches had been constructed to carry it out upon the desert.

The location of this work is in the bed of ancient Lake Lahontan, and embraces what was long known as Fortymile Desert, one of the most desolate and arid spots on this continent.

The great dams on the Truckee and Carson rivers, the former 110 feet in height, are beautiful and finished products of modern engineering. The long lines of canals, many of them large enough to carry rivers, in places are lined with cement, and obstacles in the

TRUCKEE-CARSON PROJECT, NEVADA.

Looking west up the Truckee Canal from top of Tunnel 2, showing a completed portion of the cement lined canal station.
(W. B. Lubken, January 19, 1905.)

CONGRESSIONAL PARTY INVESTIGATING THE HEADWORKS OF THE MAIN TRUCKEE CANAL, NEVADA, JUST BEFORE THE CHRISTENING OF THE NEW HEADWORKS, TRUCKEE-CARSON PROJECT, JUNE 17, 1905.

route, such as hills, are tunneled and the tunnels are cement lined. Already the first unit of this project is practically completed, the works providing for the irrigation of approximately 200,000 acres of land, 75 per cent of which belongs to the Government.

The average elevation is about 4,000 feet above sea level. The principal town is Fallon, which lies almost in the center of the tract to be irrigated. This thriving little city which to-day has a population of 1,000 and is the terminus of a branch of a transcontinental line of railroad, three years ago possessed a population of 16 people. Its very rapid growth is due entirely to the work of the Government.

The soil is adapted to the cultivation of a wide variety of crops, and is of inexhaustible fertility. The valley is filling up with a desirable class of settlers, and 500 choice 80-acre farms are ready and waiting for practical farmers.

COLORADO.

Uncompahgre Valley project.—The Uncompahgre Valley project in Colorado in many respects has presented more difficult problems than any other work undertaken by the Service. The engineers from the very first step have encountered trouble.

The topography of the country is probably the roughest in the United States. Here was a canyon through which no man had ever passed. It was necessary to explore it in order to locate a site for a tunnel. An engineer and an assistant made the attempt, and after incredible hardships succeeded. The topographers who followed to complete the surveys experienced unheard-of trials, but they, too, accomplished their task. Then a road into this frightful gorge was constructed—a remarkable road, with grades out of the canyon 24 per cent in places. Heavy machinery was brought in and a power plant installed. River Portal became a village with a store, a school, a public reading room, machine shops, cottages, and a hospital. Three crews of men, each working eight hours a day, were set to work in the bottom of the canyon driving a tunnel under a mountain 2,000 feet high.

This tunnel is to furnish an underground waterway, with cross section of $10\frac{1}{2}$ by $11\frac{1}{2}$ feet and nearly 6 miles long, to carry the waters of Gunnison River into the Uncompahgre Valley. Simultaneously other crews began the same work on the other side of the mountain, and night and day the drills were kept boring into the rock and shale, each crew vying with the other to achieve a record. For a time work was carried on from four headings. The tunnel has been driven 18,000 feet, or $3\frac{1}{2}$ miles, to date. A world's record has been made, 823 feet having been driven in one month. The records on the Simplon Tunnel in the Alps do not equal this. One gang of laborers drove 7,500 feet in one year.

Gas, cave-ins, and subterranean springs have all interposed difficulties requiring the utmost care in the prosecution of the work. At frequent intervals heavy flows of water have been encountered. As the tunnel is progressing in the downhill direction the water tends to flow to the face, where it soon floods the working spaces. This has required the installation of complete pumping facilities, consisting of two centrifugal pumps, one triplex pump, two duplex pumps, and about 1 mile of 8-inch water column. At the present time the pumps are discharging about 250,000 gallons per 24-hour day. The maximum amount of water pumped at any time was at the rate of 750,000 gallons per 24 hours.

The shale through which the tunnel has been driven is very rich in fossils. At one point about 2 miles from the West Portal and some 800 feet under the earth's surface there was encountered a series of shell beds. The shells are as white as seashore shell deposits, and have been buried in successive layers of shale. The beds vary in thickness from 1 to 18 inches, and extend horizontally for a distance of 500 feet.

Of the 17,000 feet of tunnel, more or less, driven under the direction of the Reclamation Service, about 3,800 feet were in heavy ground, consisting of adobe mud, gravel, and sand; 800 feet were in shale overlaid with heavy material; 7,300 feet were in blue shale, and 4,400 feet were in some form of igneous rock or metamorphic granite.

While the tunnel excavation was going on, many miles of canal were dug, some of which are in exceedingly unfavorable country.

The Uncompahgre Valley has a general elevation of 5,000 feet, but owing to the lofty ranges of mountains which surround it, the climate is mild and equable. The soil of the valley is of unusual fertility, and this section is noted for its fine fruits.

About 20 per cent of the irrigable land is subject to homestead entry under the provisions of the reclamation act. The farm unit on public land for first-class fruit land will probably be 40 acres, while on other public lands suitable for growing grains, sugar beets, and alfalfa, 80-acre tracts will be filed upon. About 60,000 acres are suitable for raising first-class apples and peaches. Some fruit orchards 12 years old have produced from $400 to $500 per acre net in this valley. The bottom lands, comprising from 80,000 to 90,000 acres, are adapted to the growing of alfalfa and sugar beets. During the last season many farmers made from $50 to $80 per acre net from the latter crop. At the proper time filings upon these lands should be made through the local land office at Montrose, Colo. No water for irrigation can be delivered prior to the crop season of 1909.

MINIDOKA DAM AND REGULATING DEVICES.

View taken from north end, Minidoka project, August 29, 1906. (F. C. Horn.)

IDAHO.

Minidoka project.—The Minidoka irrigation project is located in Lincoln and Cassia counties, Idaho, and embraces an area of about 150,000 acres of sagebrush land on both sides of Snake River. The area to be benefited was all Government land, and was divided in farm units of 40 and 80 acres. Practically all of the land has been filed upon by bona fide settlers. The average elevation is about 4,200 feet above sea level. The irrigable land is a vast unbroken plain possessing soil of great fertility, a deep sandy loam free from alkali, and covered with a heavy growth of sagebrush. The country is lacking in salient topographic features. Knobs and ridges occur here and there, and near the river there is a belt of low sand dunes which nowhere rise higher than 10 feet above the level of the surrounding country. The land slopes generally southwestward rather than toward the river.

The Minidoka dam.—The location of this dam is about 8 miles southwest of Minidoka, at a point where the channel of the river has been crossed by recurring lava flows of the earlier geological ages. A ridge of lava probably extended at one time entirely across the river channel at this point, and the stream has gradually cut its way through it, producing a comparatively narrow opening and a series of rapids. Above the dam site the valley widens out somewhat, forming a small storage reservoir; below it the valley consists of broad and extensive flats suitable for irrigation.

The purposes of the dam are mainly control, diversion, and power development. To provide for these purposes and to care for the immense floods to which the river is at times subjected, the dam and appurtenances consist of the following parts: The headworks of the north-side canal; the connecting concrete wall extending from this structure to the sluiceway; the sluiceway, including the controlling works and power-canal penstocks; the main earth and rock-fill dam; the spillway; the headworks of the south-side canal, and an earth embankment carried to high ground on the left of the river.

The headworks of the north-side canal and the controlling works, including the connecting wall located on the right bank of the river, form a continuous concrete structure about 350 feet long, and contain about 8,200 cubic yards of concrete and about 55,000 pounds of reinforcing steel. The headworks of the canal contain nine gates, each 5 feet wide by 7 feet high, and the controlling works contain five Coffin gates, each 8 feet wide by 12 feet high. The controlling works are founded throughout on solid rock.

The main dam is of the gravity type, and is composed of rockfill, earth, and gravel, with a concrete masonry core. The height of the dam above bed rock is about 80 feet, and above the original bed of

the stream about 60 feet, and its length is about 625 feet. The concrete core wall is built upon a solid rock foundation throughout the entire length of the dam, and at each end reaches to within about 11 feet of the top of the earth and rock part of the dam, while through the central portion its top is 44 feet below the crest of the dam. On top the dam is 25 feet wide, and the bottom width averages about 300 feet. The downstream part of the dam is built of loose rocks of large size, the minimum weight being 1,000 pounds, the central part of gravel and small rocks, increasing in size toward the large rocks on the lower side, and the upstream part of earth and gravel with riprap covering on the upper portion. The volume of this portion of the structure is 191,000 cubic yards.

At the south end of the earth and rock dam is a concrete spillway built upon solid rock for nearly half a mile in length. This spillway follows along a broken undulating ridge of lava that has been previously mentioned as extending across the river at the dam site. The spillway is therefore very sinuous in its course, following as it does the highest portion of this ridge, and is of varying height, the maximum being 14 feet. In two or three short spaces it is discontinuous, as the surface of the ridge rises above the maximum elevation of the water in the reservoir. The elevation of the crest of this spillway is 10 feet below the top of the dam, 48 feet above the bottom of the sluiceway, 7 feet above the gate sills of the north side canal, 6 feet above sills of the gate of the south side canal. This structure contains over 4,000 cubic yards of concrete.

At the south end of the concrete spillway or weir are located the headworks of the south side canal, built of reenforced concrete and having 12 cast-iron gates, each 5 feet wide by 6 feet. There were used in this structure about 250 cubic yards of concrete. From this point an earth embankment about 800 feet in length and averaging 10 feet in height completes the necessary inclosure of the reservoir above the dam.

The channel of Snake River was closed by the rock fill in April, 1906, and the entire flow was discharged through the regulating gates. The flood flow of this stream was somewhat above normal, the maximum discharge at this point, amounting to 24,292 second-feet, occurring June 20, 1906.

The natural conditions are usually favorable for the development of power. A very good site for a power house exists on the north side of the river immediately below the dam. The foundation will be blasted out of solid rock and the water will be delivered to the wheels by means of steel conduits and a supply canal about 150 feet in length. Up to July 15 the natural flow of the stream will be about 5,400 cubic feet per second. With storage at the headwaters this flow can be maintained throughout the year and all of it utilized

for power. It is believed that the power which can be developed from all sources under this system will range from 11,000 to 30,000 horsepower.

The main south-side canal has a total length of 13 miles and a capacity of 100 second-feet. It is designed with a view to enlarging it at some future time to a capacity of 800 second-feet. It is 20 feet wide on the bottom, with side slopes of 2 to 1. In fills which occur at a few places it is 46 feet wide on the bottom, the banks being of the full dimensions required by the enlarged canal. In shallow cuttings a berm is left on the inside so as to admit of enlarging it to a full bottom width of 46 feet at a minimum expense. This canal will have a capacity of 1 second-foot for each 80 acres of land and will irrigate about 8,000 acres by gravity.

The main north side canal is 30 feet wide on the bottom, has side slopes varying from ½ to 1 to 1 to 1, and will carry water to a depth of 10 feet for the first 9,000 feet. It is mostly in solid rock. Near the end of the rock cut the canal will drop 12 feet, from which point for a distance of 5 miles it will be mostly in earth, with a bottom width of 46 feet, inside slopes 3 to 1, outside slopes 2 to 1, to carry 7.5 feet of water. The banks will be 10 feet high and 8 feet wide on top.

All of the principal structures in the main canal and branches consist of concrete masonry. The inside slopes of all canals in earth on the north side are 3 to 1, the outside slopes being 2 to 1, the width of the banks on all the principal canals being not less than 8 feet and smaller laterals 6 feet. All the banks will be carried 2 feet above the water surface in the canal. In constructing these canals no runways are allowed on the inside slopes, the material excavated between the banks being hauled up the slope, the tramping of the teams being evenly distributed over all parts of the bank.

Plans for storage.—As the minimum flow of the Snake River is appropriated for other canal systems, an elaborate storage system has been designed to furnish the supply required for the Minidoka project. For a number of years the Reclamation Service has been making surveys of the several lakes on the headwaters of Snake River with a view of utilizing them for storage purposes. The first of these to be utilized is Jacksons Lake, on the south fork of Snake River, in Wyoming. Work has been begun on a temporary dam in the outlet of the lake to raise the surface of the water 10 or 15 feet. This dam will be constructed of log cribs filled with gravel. The reservoir thus formed will have a capacity of from 250,000 to 350,000 acre-feet. At some later time a permanent structure having a height of 40 feet will be constructed at this point to raise the lake's surface 30 feet, providing a reservoir having a capacity of from 800,000 to 1,000,000 acre-feet. This work is being done by force

account, since its character, the shortness of the season, and the remoteness of the site from railroad points did not tend to make it inviting to contractors.

A remarkable transformation.—In May, 1904, the Minidoka tract was practically uninhabited. The writer drove across this desert and camped for the night on the banks of Snake River at a point which was then selected as the site for the future metropolis of the valley. With the supervising engineer he drew a rough plan of the town, which was subsequently approved by the Department. That night, save for our camp fires, there was no other evidence of human habitation within 30 miles of us, only a vast expanse of sage brush, extending to the horizon. To-day you reach this point on a railroad, and pass through three towns to get there. These towns contain more than 150 business establishments, including 3 newspapers and 3 banks. They are well supplied with schools and churches. Every 80 acres of that desert now has a family living upon it, and where only a little over two years ago the desert held full sway, nearly 4,000 people are settled to-day. The sales of lots in those new towns netted Uncle Sam more than $60,000, and the lots are not all sold yet.

WYOMING-NEBRASKA.

North Platte project.—The North Platte project comprises all of the work on the North Platte River, extending from the town of North Platte on the east, near the one hundred and first meridian, to the point where the North Platte River enters the State of Wyoming from Colorado, at about the one hundred and seventh meridian, a distance which, measured by the river, is about 500 miles. The project lies 100 miles north of Cheyenne. It may be reached from the north by the Chicago and Northwestern and the Burlington railroads; from the south by the Union Pacific and Colorado and Southern railroads from Cheyenne, and from Denver and the east by the Burlington Railroad. The project extends from a point on the east which is generally accepted as the eastern boundary of the arid region, namely, the one hundredth meridian, to within a short distance of the Continental Divide.

In the easterly portion the rainfall is at times sufficient to grow crops, while in the westerly portion arid conditions are found. According to the last census, within the drainage basin of the Platte River is found the largest area of land irrigable by one stream in the United States, and the value of improved agricultural land is probably as high as any other section, with the possible exception of the fruit belts of California.

The elevation varies from 3,500 feet to considerably over 6,000 feet, the portion lying within the boundaries of the State of Nebraska

being all under 4,200 feet, or 1,000 feet lower than Denver, while that lying in Wyoming is from 4,000 to 6,000 feet, or the greatest elevation reached, and about the same as Cheyenne.

The project may be divided into a number of subprojects, as follows:

First. The Pathfinder reservoir, under construction since January, 1905, which will probably be completed in 1908, will store all the surplus and flood waters of the North Platte River and furnish all of the other subprojects, which consist of canals, with an ample supply of water. The capacity of the reservoir is about 326,700,000,000 gallons, or sufficient to cover 1,000,000 acres of land 1 foot deep. The dam will be one of the greatest masonry dams in the world, 210 feet high above the river bed, containing 53,000 cubic yards of masonry, and costing probably $1,000,000.

Second. The Interstate canal and its tributary systems, on the north side of the North Platte River. This canal heads at Whalen station, on the Chicago, Burlington and Quincy Railroad, about 8 miles above old Fort Laramie, and extends easterly to range 49 west, or about 15 miles east of the point where the Black Hills division of the Burlington Railroad crosses the North Platte River at the town of Bridgeport. The subproject has been under construction since the spring of 1905. One hundred miles of the canal are now completed. Water was first delivered in 1906 to some 20,000 acres, and will be delivered to more land in 1907.

Third. The Goshen Hole subproject, on which only preliminary surveys have been made, consist of the Goshen Hole canal, heading at the town of Guernsey, Wyo., on the North Platte River, and extends southeasterly about 140 miles, covering more than 200,000 acres of land on the south side of the North Platte River, part of which is in the State of Nebraska.

Fourth. The Fort Laramie canal, which has the same heading as the Interstate canal, but on the south side of the river extends easterly to about range 52 west, the length being 130 miles and the area covered 50,000 acres, 30,000 acres being in Wyoming and 20,000 in Nebraska.

Meteorology.—The maximum temperature in summer reaches 102° F. The minimum in winter is from 15° to 40° below zero. It must be remembered in this connection, however, that these low temperatures last for a very short period of time. It is seldom that the thermometer reaches zero every night for any ten consecutive nights, the cold snaps, as they are called, generally lasting from one to three days. The precipitation varies from 12 to 24 inches. During the season of 1906 about 24 inches fell, while in 1904 the recorded precipitation was but 13 inches. The maximum rainfall during any one

month varies from 3½ to 4½ inches. The average precipitation for the year is 14.84 inches.

Physical features.—The lands under the Interstate canal have a minimum elevation of 3,600 feet at Bridgeport and a maximum elevation of 4,260 feet in the vicinity of Fort Laramie.

The valley is about 15 miles wide, the greater part of which lies on the north side of the river. To the north and south are rolling sand hills and to the west rather rough and broken plains country. Both these regions furnish excellent grass, and are given over almost entirely to range purposes. The lands to be irrigated are flat mesa or table lands lying from 50 to 100 feet above the river. Between this mesa and the river there is generally bottom land about 1 mile in width. This land has been irrigated for a number of years, the crops being grain and grass.

Soil.—The character of the soil is very similar to that of the plains region. It consists of a sandy loam, with a marked absence, however, of the adobe soils farther south. The native vegetation consists of Buffalo grass, Gramma grass, what is locally known as Wheat grass, otherwise Bluestem, and Blackroot. All of these afford most excellent range where not overgrazed. Wheat grass in particular, which soon appears wherever the ground is irrigated, makes a most excellent hay and brings on the market at Omaha, Kansas City, and Denver a higher price than Timothy. The cactus or prickly pear is much in evidence, indicating the richness of the soil. This plant is entirely destroyed by the first plowing, and wherever it grows the land is considered the most desirable. There is a marked absence of sagebrush under the Interstate canal.

Water supply.—The water supply for irrigation is practically unlimited in that there is a greater amount of water annually flowing down the river than can be profitably utilized by the available irrigable lands. With the construction of the Pathfinder reservoir, which is capable of storing more than one-half of the entire annual run-off, the settlers under any of the Government canals are assured of an ample supply of water at all times of the year.

Progress to date.—In 1907 water will be turned onto probably 60,000 acres of land, 20,000 acres being in Wyoming and 40,000 acres in Nebraska. Late in the fall of 1907 it is probable that an additional 40,000 acres will receive water, making in all, by the spring of 1908, 100,000 acres ready for crops. These farms will average about 100 acres each of irrigable land. In other words, 1,000 families should be on the land and actively engaged in agriculture by the spring of 1908.

Towns.—The principal towns embraced in the interstate canal project, beginning at the head of the canal, are old Fort Laramie and Torrington, Wyo., Morrill, Mitchell (the Government headquarters),

Scottsbluff, Minatare, Bayard, and Bridgeport, Nebr. The distance by the railroad between old Fort Laramie and Bridgeport is about 90 miles. Each of the towns named are from 10 to 15 miles apart. They are similar at present, and no one town appears to have the advantage over the other. The largest have a population of about 1,000 persons. The railroad, which extends the entire length of the project, was built in 1899, at which time the above-named towns were established. No material growth occurred in the valley, however, until 1904, when the Government began work, since which time all of the towns have more than doubled in population.

CALIFORNIA–ARIZONA.

Yuma project.—A very general interest is being shown in the work of the Reclamation Service, on what is called the Yuma project in Arizona and California, in the valley of the Colorado River. The engineering works are unusual and unique, occasioned by the difficult physical conditions and the immense flood discharge of the Colorado River.

The work of the engineers was greatly complicated by the unfavorable character of the bed of the river, the diamond drillers having sought in vain for solid rock upon which to rest a dam, and, further, by the fact that a large area of the bottom lands are annually inundated in times of flood. These conditions necessitated the construction of a dam of a type never before attempted in this country, and also the building of many miles of levees to protect the lower lands from flooding.

The Laguna dam is of the India weir type, which has been tried successfully during the past fifty years at numerous places in India and Egypt under similar conditions. It consists of a loose rock structure with a paving of stone 1½ feet in thickness on the downstream slope, tied together with three parallel walls of steel and concrete running longitudinally betwen granite abutments on the two sides of the river. The dam will have a length of 4,780 feet, a height of 19 feet, and a maximum width up and down stream of 257 feet. It will contain 356,000 cubic yards of loose rock resting upon a foundation of sand. The estimated weight of the structure is 600,000 tons.

This dam is not designed for storage, but will create a settling basin of relatively quiet water 10 miles in length above it. The Colorado River carries enormous quantities of silt, and to prevent this sediment from filling the canals sluiceways have been designed especially for this purpose. At each end of the dam, and constructed in solid rock, will be a sluiceway 3,000 feet long, 200 feet wide, and over 12 feet deep, excavated to the depth of low water in the river.

These sluiceways will be controlled immediately below the canal intake by large gates operated by hydraulic machinery. When these gates are closed the portions of the sluiceways above them become immense settling basins from which it is planned to take the water into the canals by a skimming process, so that the entire capacity of the canals can be furnished by drawing but a foot in depth of water from the surface. When the silt has accumulated to a sufficient extent the sluice gates will be opened and the great volume of water, estimated at 20,000 cubic feet per second, which will then pass through the sliceways will carry the sediment out into the river.

The main canal on the Arizona side will cross the valley of the Gila River above Yuma in a pressure pipe laid under the stream, the top of which is to be several feet below the lowest point of the stream bed. This structure will be of steel and concrete and about 3,000 feet in length.

The shape of the levees adopted to protect the lower lands from overflow is the same as has been developed by years of experience along the Mississippi River. These levees will have a slope of 3 feet horizontal to 1 foot vertical on the land side. They will be 8 feet wide on top and 5 feet above the highest water mark. The levees will be 4,000 feet apart, one on each side along the Colorado, and 3,200 feet apart along the Gila River. The total length of levees will be 73½ miles.

When the works are completed 97,000 acres will be ready for settlement. The lands to be irrigated rival in fertility and productiveness those of the famous valley of the Nile. They are especially adapted to intensive farming. This section of the country is essentially a region of small farms, owing to the almost continuous growing season, and the production of high-priced fruits and vegetables. Ten acres in careful cultivation is sufficient to support a family in comfort.

MONTANA.

Huntley project.—This project contemplates the reclamation of about 30,000 acres of land located along the Yellowstone River in southeastern Montana. These lands lie between Huntley, at the junction of the Northern Pacific and Chicago, Burlington and Quincy railroads, and Bull Mountain station on the Northern Pacific Railway, and are therefore favorably located with respect to transportation facilities. The Huntley project lands are part of the ceded strip of the Crow Indian Reservation, and as such are subject to the provisions of the act of Congress approved April 27, 1904. Under the provisions of this act the lands withdrawn for reclamation purposes can only be settled under the terms of the reclamation act of June 17, 1902 (32 Stat. L., 388), and in addition, the settler must pay

$4 per acre for the benefit of the Crow Indians. The Huntley project lands were withdrawn by the Secretary's order of May 21, 1906, and will probably be opened for settlement in July, 1907. Announcement of the date of opening will be made in the public press in due time.

The construction of the irrigation works under the Huntley project was authorized by the Secretary of the Interior April 18, 1905, and the work was about two-thirds done on January 1, 1907. The main canal, headworks, and incidental structures are being built in the most substantial manner. The culverts, turn-outs, and waste ways are made of concrete, reenforced with steel. The three tunnels, aggregating 2,650 feet in length, are lined with concrete throughout. The small turn-outs and culverts on the distributing system are built of wood, but are heavy and well constructed. A special feature is the pumping plant near Ballantine, which utilizes the power developed by a necessary drop of 33½ feet in the main canal, to lift about 56 cubic feet per second of water about 50 feet, to the high-line canal. The main canal is about 32 miles long, and the high-line canal about 7 miles long. It is proposed later to extend both these canals to water additional land. A telephone system has been installed to facilitate construction work, and will be an important part of the operating system.

The climate is good, the temperature ranging from 100° F. to —35° F., and the rainfall varying from 9 to 15 inches annually.

The soils vary from a fine sandy loam to a heavy clay, and in some places are strongly impregnated with alkali. The waste-water ditches are laid out so as to prevent the rise of alkali on the good land, and to allow of the poorer pieces being reclaimed.

The crops will be largely forage crops and sugar beets. There is a fine free-range country adjoining the valley, which makes stock raising profitable when winter feed is procurable. A new beet-sugar factory at Billings, 13 miles west of Huntley, seems to be very successful, and with a market as at present the raising of beets is very profitable. Apples and the small fruits can be raised.

Sun River project.—The ultimate development of this project involves the reclamation of 256,000 acres of land tributary to the Sun River. A large percentage of the land is public domain. The land is a broad prairie, extending from Teton River on the north to and including the Sun River Valley on the south. The irrigable tract has a length east and west of about 70 miles and north and south of about 30 miles. The topography of the country and water supply combine to make the project an attractive one.

Fort Shaw, the first unit to be reclaimed, will be located on the south side of Sun River and contains an area of 17,000 acres. The unregulated flow of Sun River will afford ample supply for this land during the early irrigation season, and to insure an ample supply

throughout the year a storage reservoir will be constructed on Willow Creek. This reservoir will have a capacity of 20,000 acre-feet, the drainage of Willow Creek being ample to supply this amount in seasons of low run-off. The topography and quality of the soil combine to make it practicable to divide the Fort Shaw tract into small farm units.

Good grazing land surrounding the project will also contribute to the success of the irrigators. While the farms will probably be restricted to 80 or 40 acres of irrigable land, it will be possible to give a large per cent of these farms an area of grazing land, bringing the total farm unit up to 160 acres. It is probable that water will be available for irrigation in the season of 1908.

Milk River project.—The Milk River project contemplates ultimately the reclamation of 250,000 acres of land in the Milk River Valley between Havre and Glasgow, Mont. In addition to regulating the discharge of the Milk River, the water supply will be supplemented from the St. Mary Lakes. It is proposed to store the discharge of the St. Mary drainage basin and conduct the water by canal 26 miles long, having a capacity of 1,000 cubic feet per second, to the headwaters of the Milk River.

Construction work was commenced on the St. Mary canal in the season of 1906. A plant has been assembled and work will go forward during the season of 1907. Contracts will be so arranged that work can be given to the Blackfeet Indians, who reside there.

NORTH DAKOTA—MONTANA.

Lower Yellowstone project.—This project contemplates the diversion of Yellowstone River, at a point 17 miles northeast of Glendive, Mont., for the irrigation of 66,000 acres of land lying in northeastern Montana and northwestern North Dakota. The land is classed as follows: Montana, private lands, 14,618; public lands, 13,522; railroad lands, 16,742 acres. North Dakota, private lands, 12,786; public lands, 8,332 acres. The public lands under the project number 21,854 acres; railroad lands, 16,742 acres, and private lands, 27,404 —a total of 66,000 acres.

The public lands available for homestead entry in Montana should, at the proper time, be filed upon through the land office situated at Miles City, Mont., and those in North Dakota at Williston, N. Dak. The lands to be affected by this system are tributary to the Northern Pacific Railway line which passes through Glendive, 19 miles from the head gates, and the Great Northern Railroad, which has a station at Buford, 2 miles from the lower end of the project. The farm unit on this project will probably be 80 acres. Work is now in progress on the main canal and lateral system.

NORTH DAKOTA.

Pumping projects.—Three pumping projects are contemplated in western North Dakota for the purpose of raising water from the Missouri River to irrigate bench lands which can not be reached by feasible gravity systems. Steam and electric power will be used for pumping, the power to be developed from lignite coal, which is found in ample quantities on Government lands adjacent to the projects.

Williston project.—This is one of the most unique projects of the Reclamation Service. The Missouri River has a habit of constantly cutting its banks and changing its channel, so that it would be impossible to locate any structure for the diversion of water by gravity unless enormous expense were incurred to protect it from the scour of the stream; moreover, its grade is so flat that any gravity canal would be of prohibitive length. Fortunately, large beds of lignite were discovered in the vicinity, affording cheap fuel, and the engineers conceived the plan of building a power house at the coal mines and conveying the power by electric conduits to the river. Their ingenuity did not cease here. Instead of the costly works required to protect the banks, the pumps will be located on floating barges which will accommodate themselves to changes in the channel and in the water level.

The water will be delivered through pipes with flexible joints into several basins located at sufficient distance from the shore to be safe from encroachment by the shifting river. From these basins the water will be pumped into canals to cover the irrigable lands. These basins will also serve for the purpose of settling the silt, large quantities of which are carried in solution by the Missouri River. During the winter season the barges will be drawn out of the water and hauled to points where they will be safe from ice gorges and sudden freshets and the basins can be cleaned out.

About 19,000 acres in the Muddy Valley in and about Williston will receive water from this system. The bottom lands adjacent to Buford and Trenton and the famous Nesson Valley, comprising an area of approximately 21,000 acres, will also be benefited by pumping systems.

The soil is loam, with a slight mixture of sand, and produces good crops without irrigation in years when there is unusual rainfall. With an assured water supply this valley will undoubtedly be one of the most productive in the Northwest. It is adapted to the growing of all the hardy cereals and forage plants, and sugar beets will prove a profitable crop. Garden vegetables do well, irrigated potatoes yielding as high as 450 bushels per acre. There is an extensive range for live stock, and this should assure a profitable market for

all forage crops raised on the irrigated farms. The lands lie on the main line of the Great Northern Railroad, a transcontinental route, and the Twin Cities and Duluth offer splendid market facilities.

The climate is exceedingly healthful and invigorating; the elevation above sea level is about 2,000 feet, and the air is clear and bracing.

The city of Williston is the county seat, and has a population at present of about 2,200. It is a central distributing point for a section of country extending approximately 60 miles in each direction. A town site is now being laid out on the Government land about 7 miles north of Williston, near the northern limits of the project.

Buford-Trenton project.—This project is located on the north bank of Missouri River, near the Montana State line. The initial unit will include about 12,000 acres of bench and bottom lands extending from Buford station to Trenton station, on the Great Northern Railroad. The second unit will include the Trenton flat, which lies midway between the Williston and Buford projects.

The electrical and pumping machinery for the two stations required for the irrigation of the first 12,000 acres is now under contract, and the installation will be completed about October, 1907. The entire canal system will be completed in 1908. The power for operating these pumping stations and those to be erected later for the Trenton flat will be transmitted electrically from a main generating station near Williston.

Nesson project.—This project is about 30 miles southeast from Williston, and about 20 miles south of the Great Northern Railroad. It includes bench and bottom lands on both sides of the Missouri River, and contains about 15,000 acres. About one-fifth of this land is public domain and will be open to settlement prior to the completion of the irrigation works. It is proposed during the coming season to provide for the installation of the necessary pumping machinery and the construction of a canal system to irrigate about 12,000 acres. Electric power will be distributed to four pumping stations from a main electric generating station located adjacent to the lignite coal mine, from which the fuel will be obtained.

KANSAS.

Garden City project.—This project contemplates the recovery of ground water in the Arkansas Valley in the vicinity of Garden City by pumping, and its distribution by means of an existing canal known as the Farmers' ditch. The system, which is nearing completion, consists of a series of separate pumping stations, each discharging into a concrete-lined flume or surface conduit, which will carry the water to the main canal. The water will be delivered into

the Farmers' ditch about 1 mile northeast of its headgates. The entire plant is to be operated by electricity from a central power station located near the middle of the line of pumping stations.

The bottom lands at this point are very wide and constitute an excellent catchment area for rainfall, and the gravels beneath the bottom lands form an underground drainage for the contributory watershed, extending both north and south of the river valley. There is practically no surface run-off from this portion of the plains. The ground is so level and porous and the gravels beneath the surface so ample that they act like drains in removing all of the rainfall that is not appropriated by the vegetation and evaporation. The entire pumping plant is designed to recover an average of 100 second-feet of ground water for a period of 150 days, which is equivalent to a total of 30,000 acre-feet for the irrigation season. A portion of the water recovered will be carried under the Arkansas River by a siphon 800 feet long, with a capacity of 100 second-feet. The Farmers' ditch covers portions of the uplands and bottoms which possess soil of excellent quality. The semiarid region of western Kansas requires but a small amount of water per acre of irrigated land, as the natural rainfall and the quality of the upland soil renders possible a very high duty of water.

The value of the land in this part of Kansas in its natural condition is from $5 to $10 per acre. When reclaimed by irrigation it is easily worth from $100 to $150 per acre. The principal crops are sugar beets and alfalfa, considerable quantities of which are already under cultivation. Sugar-beet factories are already located within easy shipping distance from Garden City. Back of the lands to be watered are wide strips of excellent grazing lands, which will grow cane and forage plants without irrigation. Water will be furnished to about 5,000 acres during the summer of 1907.

SOUTH DAKOTA.

Belle Fourche project.—In many respects this is one of the most remarkable irrigation projects yet undertaken by the Government. It involves the construction of one of the largest earth dams in the world, a structure over a mile long, 100 feet high in the highest place, and 20 feet wide on top. Its cubical contents will be 42,700,000 cubic feet, or about one-half that of the Pyramid of Cheops, which is estimated to have occupied nine hundred years in construction. This dam will create an artificial lake larger than any body of water in the State, a lake 60 feet deep, with a water surface of about 9,000 acres when filled.

About 65 per cent of the land under this project belongs to the Government. More than 1,000 new farms will be created in a valley where the principal product has been low-grade range cattle, and the

value of lands which now ranges from $5 to $10 per acre will be increased to $75 and upward. Work has progressed to a point where water can be delivered to 10,000 acres in the summer of 1907.

WYOMING.

Shoshone project.—This project contemplates the utilization of a portion of the surplus waters of the Shoshone River for the reclamation of land in the northern part of Bighorn County, Wyo. It involves the construction of the Shoshone dam, a concrete masonry arch, and the highest structure of its kind in the world. This dam will lock a very narrow canyon, so that in cubical contents it will not compare with any of several other dams, but in its great height it exceeds them all. From bed rock to top it will be 310 feet; at its base it is only 85 feet long, and on top only 200 feet. The preliminary work on this structure was attended with great difficulties, owing to the almost inaccessible location of the dam site and the unexpected conditions which were found in the river bed. The diamond drills went down 88 feet in places before finding a permanent base, and bowlders 38 feet in thickness were penetrated, resting on beds of sand and gravel.

As in Arizona, it was necessary to construct a road up the canyon for several miles. The work is well under way, and it is expected that water will be available for a considerable area in the season of 1908. When completed the Shoshone project will cost $3,500,000, and will irrigate 100,000 acres of land.

NEW MEXICO.

Rio Grande project.—The Rio Grande project provides for the irrigation of 180,000 acres of the rich valley lands along the Rio Grande in New Mexico and Texas. The engineering works involved are the Engle dam, to be built of cyclopean concrete, arched upstream, and 255 feet high. Its length at crest will be 1,150 feet, and at river level 400 feet. This dam will create an artificial reservoir 40 miles long, with a capacity of 2,000,000 acre-feet. As the estimated cost of this project is $7,200,000, it has not been possible to commence the construction of the principal works, but the sum of $200,000 has been set aside for the construction of the Leasburg diversion dam and the enlargement of the Las Cruces canal, a unit of the main project.

This diversion dam is a concrete structure 600 feet long, connected with the old Las Cruces system by a canal 6 miles long. Construction was begun in November, 1906, and 15,000 acres of land in Mesilla Valley will be supplied with water during the irrigation season of 1907. When completed this system will supply water to 40,000 acres which, owing to the destruction of the old canal system, are absolutely without water supply.

Hondo project.—This project, which is practically completed, pro-

BOX CANYON, SHOWING THE DAM SITE IN THE END OF THE CANYON.

View taken just below the dam site looking upstream. Shoshone project, Wyoming. This dam will be the highest in the world—310 feet.

HONDO PROJECT, NEW MEXICO. HONDO RESERVOIR, LOOKING NORTH FROM OUTLET TOWER.

(W. B. Lubken, January 31, 1907.)

vides for the diversion and storage of flood waters of Hondo River, a tributary of the Pecos, and the reclamation of about 10,000 acres of land in the vicinity of Roswell.

The reservoir site is a large natural depression, the storage capacity of which has been increased by the construction of five embankments between the surrounding hills. The water is diverted by means of an earthen dam 20 feet in height and conveyed to the reservoir through a canal with a bottom width of 70 feet and a capacity of 1,200 cubic feet per second. This canal is provided with a weir at its lower end, over which the water will flow, allowing the silt to gather behind it and be sluiced out at intervals. The outlet canal connects the lowest point in the reservoir with the river, passing out through a gate in one of the fills. The channel of Hondo River will be used for carrying the irrigating water a distance of about a mile. At this point it will be turned by a small concrete diversion dam into the distributing canals, one on each side of the river.

The area to be irrigated is all first-class land, free from alkali, and when irrigated will be easily worth $100 per acre if planted in corn or alfalfa. If used for fruit raising it will have a higher value. Water will be furnished during the crop season of 1907. The Pecos Valley and Northwestern Division of the Santa Fe Railroad has a line into Roswell. It may be possible to purchase lands from the present owners.

Carlsbad project.—The principal works under the Carlsbad project include the reconstruction of canals and storage reservoirs on Pecos River in Eddy County, which were built by private enterprise, to irrigate about 20,000 acres of land. The development of Pecos Valley has been brought about by individuals who installed an extensive system of irrigation works representing the outlay of more than a million dollars. On October 4, 1904, a flood in Pecos River destroyed a large portion of Avalon dam, upon which the canal system depended for its supply. The owners of the canal system were unable to repair the damages, and as property valued at not less than $2,000,000 was threatened with destruction unless a water supply were provided, an appeal was made to the Government to take the works and initiate construction. Some land will be irrigated during 1907. The land is mostly in private ownership and is tributary to the Pecos Valley and Northeastern Division of the Santa Fe Railroad.

OREGON-CALIFORNIA.

Klamath project.—The Klamath project contemplates the reclamation of about 190,000 acres of land situated in Klamath County, Oreg., and Modoc and Siskiyou counties in California. The plans involve, in addition to the irrigation of the valley lands, the reclamation by drainage and future irrigation of a portion of the Lower Klamath and Tule lakes, lands which are now either swamp or lake

bottoms. Practically all the uplands, which include the greater part of the project, are held in private ownership, a large part being in large holdings, which, under the terms of the reclamation act, must be subdivided into tracts not to exceed 160 acres, as this is the maximum area for which water can be furnished to individual owners under the law. The public lands under the project, which include a large portion of the lake and swamp areas, are at present withdrawn from entry. When these lands are restored to entry, homesteaders may file applications for available public lands. The lands in California are under the jurisdiction of the Susanville and Redding land offices and those in Oregon under the jurisdiction of the Lakeview land office. Land can be acquired at the present time only by private purchase.

The project is naturally divided in two parts, which have been commonly called the "upper" and "lower." The "upper project," which takes its water supply from the Lost River, with Clear Lake as a storage reservoir, includes Langell's, Yonna, and the upper Poe valleys. The lower project includes the lands in Klamath and lower Poe valleys and the Lower Klamath and Tule lakes. The source of water supply for the "lower project" is Upper Klamath Lake.

Construction work on the first 9 miles of the main canal and the laterals thereunder was begun in March, 1906, and it is expected this unit will be completed in 1907. From the first unit of the main canal and the little Klamath water ditch, commonly known as the Adams canal, which has recently been purchased by the United States, water can be delivered to from 12,000 to 15,000 acres during the irrigation season of 1907. The lands under the project are of good quality. The principal crops grown are alfalfa, wheat, oats, barley, rye, vegetables, and some deciduous fruits. A few experiments in sugar-beet culture show that it is probable that this crop can be successfully grown.

The principal town of the valley is Klamath Falls, located on Link River, about 1 mile below the lower end of Upper Klamath Lake. Other towns in the valley are Merrill, situated near Tule Lake, and Bonanza, situated on Lost River, within the so-called "upper project." The California and Northeastern Railway is now under construction to Klamath Falls.

OREGON.

Umatilla project.—The Umatilla project embraces 20,000 acres immediately south of Columbia River and east of Umatilla River. About 10 per cent of these lands are in public ownership. The engineering works in connection with this project consist of a feed canal from Umatilla River to the Cold Springs reservoir and a distributing system. The works are of simple character and capable of being constructed in a short time. The irrigable area under this project

lies below 500 feet in altitude, is rolling in character, and the lands are of high fertility. The climate is warm and the soil adapted to orchards, small fruits, and vegetables. Transportation facilities are excellent, the lands being within 200 miles of Portland, Oreg., or Spokane, Wash., on the main lines of the Oregon Railroad and Navigation Company.

UTAH.

Strawberry Valley project.—This project provides for the irrigation of about 60,000 acres of land in central Utah, situated from 5 to 15 miles south of Provo and on the eastern shore of Utah Lake. Water supply will be received from a storage reservoir to be built on Strawberry River, about 30 miles east of the irrigable area. By means of a tunnel 4 miles long stored water will be carried under the divide and emptied into Spanish Fork, from which a canal from 18 to 20 miles long will convey it to the irrigable area. The lands have a mean elevation of 4,500 feet.

IDAHO.

Payette-Boise project.—The Payette-Boise project ultimately will reclaim about 350,000 acres of land in the valleys of the Payette, Boise, and Snake rivers in southwestern Idaho. Of this area about five-sixths are without present facilities for irrigation. The valleys are tributary to the Oregon Short Line, the Boise, Nampa and Owyhee, and the Idaho Northern railroads.

The complete plans propose the utilization of both the Payette and Boise rivers, and include the construction of extensive storage works at the headwaters of each stream. The lands are in Ada, Canyon, and Owyhee counties and are smooth, with gentle slopes. The work of construction has been taken up by units, and several years will elapse before the whole project is completed. Several contracts have been let and work is well under way.

WASHINGTON.

Okanogan project.—This project is designed to supply water to 8,650 acres of land in Okanogan Valley in northern Washington. The water supply is estimated to be sufficient for the proper irrigation of 10,000 acres, 1,350 of which are now supplied. The farm unit, on account of the possibilities for high development in this section, will be 40 acres. Lumber for building purposes and fuel supplies are practically unlimited. The lands are tributary to the Great Northern Railroad.

Yakima Valley.—Yakima Valley contains an area of approximately 500,000 acres; with storage it is estimated the water supply is sufficient for 340,000 acres. This acreage includes approximately 100,000 acres in the Yakima Indian Reservation, which can be brought

under the canals at a moderate cost, but for which there is no late summer flow in the river. The development of a comprehensive system of irrigation in Yakima Valley can be accomplished by the successive construction of several units of a general project, the work being gradually extended to embrace the entire irrigable area.

The Tieton division, which is an integer of the great work projected in Yakima Valley, embraces an area of about 24,000 acres west of and near the city of North Yakima. The water supply will be from Tieton River, supplemented by water stored in Bumping Lake.

The Sunnyside division of the Yakima project contemplates the purchase, enlargement, and extension of the Sunnyside canal system now in operation, and in connection therewith the construction of suitable storage works at the upper Yakima lakes. The Government has purchased the property of the Washington Irrigation Company. The canal and lateral system contemplated as the first section of the work will irrigate about 20,000 acres of land in addition to the 40,000 acres now under irrigation from existing canals.

Construction of the Tieton and Sunnyside projects began during the winter 1906–7.

Wapeto project.—The irrigable lands under this project are all embraced in the Kakima Indian Reservation, south of Atanum Creek, and on the right bank of the Yakima River. This part of the reservation contains about 120,000 acres susceptible of irrigation, some 17,000 acres of which are now receiving water during the season of high water. These lands lie particularly well for easy control and in respect to soil and transportation facilities are equal to the best in the valley.

For the reclamation of these lands the plans provide for the enlargement of the old and new reservation canals which were built with tribal funds, the utilization of all of the waters of Toppenish and Sapus creeks, and the storage of 200,000 acre-feet in the Yakima Lake. An act of Congress was passed March 6, 1906, authorizing the Secretary of the Interior to make investigations to determine the feasibility of irrigating these lands, to fix the value of the present irrigation works on the reservation in order that they might be included in the cost of the project and be paid for by the water users who obtained benefits thereof. Before actual construction can begin it will be necessary to make arrangements with the Indians in order that the surplus areas in their allotments may be disposed of as provided in the law, and become subject to the payment of the purchase price from the Indians as charges for the reclamation works. It is hoped that these questions can be adjusted at an early date, so that the Reclamation Service may be able to proceed with the necessary surveys and investigations preliminary to the actual construction of the project.

INTERNATIONAL SCIENCE.[a]

By Prof. ARTHUR SCHUSTER,
Langworthy professor of physics in the University of Manchester.

The pursuit of science has always joined in sympathy men of different nationalities, and even before the days of rapid letter post and quick traveling, intercourse, especially by correspondence, exercised a considerable influence on scientific activity. Such intercourse was, however, of a personal and purely stimulating character, and only quite exceptionally was there any direct attempt to organize investigations which required a combination of workers in different localities. Within the last century, however, many problems became urgent which could not be solved without some international agreement, and special organizations came into life which have rendered a service the importance of which can not be exaggerated.

At present we are confronted with a new difficulty. International combination has become so necessary and organizations have in consequence increased to such an extent that they begin to overlap, and there has been some danger of mutual interference. Fear has also been expressed that any attempt to advance knowledge by an organized combination of workers might discourage private efforts, and therefore do mischief rather than good. It must be acknowledged that this danger exists. The proper function of combination must be clearly separated from that of private enterprise, and some general regulating control is therefore called for. The time seems ripe for a general review of the situation.

We may distinguish between three types of international organizations. The first aims simply at collecting information, the second is intended to fix fundamental units or to initiate agreements on matters in which uniformity is desirable, while in the third type of organization a more direct advance of knowledge is aimed at and research is carried out according to a combined scheme. Generally an international association does not entirely fall within any single one of these divisions, but it is useful to draw the distinction and classify the associations according to the main object which they are intended to serve.

The best example of an organization formed for the purpose of collecting information is furnished by the great undertaking initiated by our Royal Society and having for its object the systematic cata-

[a] Read before the Royal Institution of Great Britain at weekly evening meeting, Friday, May 18, 1906. Reprinted from Transactions.

loguing of the scientific literature of the world both according to the subjects and authors.[a] Twenty-nine countries (counting the four Australian colonies separately) are actively participating in this work by furnishing slips containing the entries which form the basis of the catalogue. A still larger number of countries assist by subscribing to the annual volumes.

The subjects included in the catalogue are classified according to seventeen branches of science, as follows:

[A=mathematics; B=mechanics; C=physics; D=chemistry; E=astronomy; F=meteorology; G=mineralogy; H=geology; J=geography; K=paleontology; L=biology; M=botany; N=zoology; O=anatomy; P=anthropology; Q=physiology; R=bacteriology.]

Country.	Sets.	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.	M.	N.	O.	P.	Q.	R.
Russia	14	2	2	11	6	18	15	19	20	20	13	8	38	30	5	14	8	8
France	27	1	5	11	17	1	3	10	7	5	6	15	13	12	7	3	18	16
Switzerland	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Canada	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Holland	5	1	2	1	3	1	2	1	2	3	1	4	3	3	1	1	2	3
Greece	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hungary	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Norway	3	....	....	1	1	....	1	....	....	....	....	....	2	4	1	1	2	....
India	29	5	4	7	5	2	5	2	3	4	2	5	14	5	2	....	4	6
United States	62	11	14	17	14	10	11	8	12	10	7	9	12	10	3	3	7	9
Great Britain	29	5	7	18	17	6	8	8	8	5	4	6	6	5	6	6	7	13
Austria	4	1	2	4	2	1	1	3	5	6	2	1	4	5	1	3	....	1
Cape of Good Hope	6	....	....	....	2	....	....	2	2	....	2	....	1	....	....	....	....	....
Denmark	6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Egypt	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Finland	1	1	2	2	2	1	1	2	3	1	1	1	2	2	1	1	2	1
Germany	41	6	8	14	18	2	5	3	4	5	1	13	9	8	5	2	18	7
Italy	27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Japan	15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mexico	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
New South Wales	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nova Scotia	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Orange River	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Poland	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Portugal	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Queensland	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South Australia	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Sweden	5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Victoria	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Western Australia	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	315	38	46	86	86	45	55	58	66	59	39	65	103	90	32	34	66	64

[a] The cataloguing enterprise here referred to is the International Catalogue of Scientific Literature. The original suggestion for international coöperation in the preparation of an index to science was made by Professor Joseph Henry, the first Secretary of the Smithsonian Institution, who, at the meeting of the British Association for the Advancement of Science in 1855, at Glasgow, called attention to the growing need of such an index. The "Catalogue of Scientific Papers," published for many years by the Royal Society of London, was the first fruit of Professor Henry's suggestion. The International Catalogue of Scientific Literature is an outgrowth of the "Catalogue of Scientific Papers."

The Smithsonian Institution since the beginning has represented the United States in this important international undertaking.—*Editor, Smithsonian Institution.*

Subscribers may either obtain complete sets or any of the separate volumes. The relative popularity of the different subjects is illustrated by the preceding table, which gives in the different columns for each science the volumes approximately required by each country. The figures are of course subject to variations from year to year. The first column shows the number of complete sets subscribed for in addition to the separate volumes; these presumably find their way into university or public libraries.

The popularity of the special botanical catalogue is remarkable.

We may obtain a rough idea of the scientific activity of different countries by comparing the number of slips received from them during a certain interval. The numbers given in the report published by the international convention held in London last summer and referring to all slips received, are shown in the following table.

The total number up to March, 1906, has increased to 700,000.

Country.	Slips received.	Number of journals.	Average number of slips per journal.
Austria	13,186	535	25
Belgium	2,272	174	13
Canada	537	45	12
Denmark	2,584	40	64
Finland	1,828	33	55
France	60,401	930	65
Germany	213,545	1,397	153
Holland	9,861	70	141
Hungary	2,605	35	75
India and Ceylon	2,699	31	87
Italy	21,238	300	71
Japan	3,043	42	72
New South Wales	2,049	8	256
New Zealand	440	1	440
Norway	2,017	36	56
Poland	5,820	65	90
Russia	25,741	457	56
South Africa	1,872	15	125
South Australia	159	6	56
Sweden	1,639	63	31
Switzerland	5,140	126	41
United Kingdom	56,382	488	116
United States	66,071	588	112
Victoria (Australia)	2,858	23	124
Total	504,297	5,508	90

The catalogue begins with the year 1901, but some countries send in their slips rather earlier than others, so that the time interval covered by the investigations to which the table refers is not quite the same for all. Nevertheless, the numbers shown in the table possess a certain interest. I have given in the last two columns the number of journals which different countries take into account and

the ratio of the number of slips to the number of publications. Here, again, it is difficult to estimate accurately how much value is to be attached to the figures, as there is no uniformity of selection as to what should and what should not be included in the catalogue. Journals which may only very seldom contain any paper which is to be included may unduly diminish the numbers in the last column, which are also affected by the interpretation given as to what is purely technical, and therefore to be excluded. Nevertheless, the comparison between the United Kingdom and France gives the somewhat striking result that while France is slightly ahead in the number of separate entries it contributes to the catalogue it takes account of nearly double the number of journals, and the ratio showing the number of entries per journal is therefore very small. In the case of Belgium and Canada we find also a large number of publications as compared with the slips received.

Regard must, however, be had to the fact that in the subject catalogue the same paper may furnish several entries. Especially is this the case in biological subjects, where several species may be described, for each of which a separate slip must be written out. Hence in any country active chiefly in the discovery of new species the ratio given in the last column of the table would be abnormally large. This is probably the explanation of the figures given for New Zealand. In the opinion of the director of the central bureau, the standards adopted by different countries are drawing nearer together as the work proceeds, and before long we may therefore expect to obtain valuable statistical information on the scientific activity in different countries; but this is only an incidental result of the undertaking. It may reasonably be argued that the scientific investigator ought not before he begins a research to trouble too much about what may have been done by others in the same direction, but there is no doubt that before publication he should have made himself acquainted with the literature of his subject. A well-arranged catalogue then becomes a necessity, though its value as a means of helping students differs considerably in different subjects.

The governing body of the catalogue is an international council composed of one representative from each of the countries taking part in the scheme. This council has appointed an executive committee, of which Professor Armstrong is the chairman.

The central bureau for the publication of the catalogue is in London, under the direction of Dr. Henry Forster Morley, who has a staff of 13 workers under him. There are in addition 19 experts or referees representing the different sciences. The annual office expenses, including salaries, amount to about £2,200; while the expenditure on printing, binding, and publication in the year ending March 1, 1905, amounted to nearly £4,900. The two items are just covered

by the guaranties of the different countries which, as already mentioned, take the form of subscriptions for copies of the catalogue, so that it may be said that the central office is self-supporting. After so short a time of working, this success must be a source of considerable satisfaction to Professor Armstrong and those who have helped to initiate the work. But the expenses incurred in London only represent a fraction of the total cost of the work. Most of the countries establish regional bureaus which prepare the slips and forward them to London. This really constitutes the most serious part of the work. In Germany, for instance, the regional bureaus are under Professor Uhlworm, one of the university librarians, who is helped by six assistants and devotes his whole time to the work.

I pass on to an undertaking of a very different kind, but still one which must be included in the class which primarily aims at cataloguing. The accurate determination of the positions of the stars for a particular period is a work which must precede all exact measurements of their proper motions. Hence it constitutes a fundamental problem of astronomy. The multitude of stars seen on a bright night is bewildering to the casual observer. They are described in poetical writings as innumerable, but when an actual count is made it is found that their number is really moderate, and it is doubtful if more than 2,000 stars have ever been visible to the naked eye at the same time. The use of the telescope considerably increases this number, according to the size of the object glass or reflecting mirror used. Thus, Argelander in his great star catalogue included nearly 324,200 stars which he observed through his telescope of 4 inches aperture. The advent of photography, and the manufacture of suitable lenses to be used in connection with photography, increased the astronomical output of a fine night to such an extent that it became possible to make a further and very substantial advance. The international star catalogue, which is at present being constructed, owes its origin chiefly to the hard work of Admiral Mouchez, who was at the time director of the Paris Observatory, and who became converted to the feasibility of the plan by the excellent results obtained by the brothers Henry, the pioneers in star photography. He was assisted by the energetic support of Sir David Gill, to whom the first suggestion was due. The programme of work was determined upon at an international conference which met at Paris in the year 1887. Eighteen observatories were to take part in the work, the telescopes to be used were to have an aperture of 13 inches, and such a focal length that a millimeter on the plate corresponded to one minute of arc. Each observatory had a certain region of the sky assigned to it, and undertook to cover this region four times, twice with plates of short exposure, twice with plates of long exposure, and to measure all the

stars appearing on the short exposure photographs. The long exposures were intended for reproduction in the form of charts, and are only taken by some of the observatories. As there are about 400 stars on each plate and it takes about 600 plates to cover the share of one observatory once, this means that each observatory has to measure nearly 500,000 star places, and that the complete catalogue will give the positions of nearly 4,500,000 stars. This includes all stars down to the eleventh magnitude.

The following is a list of observatories taking part in the work:

For the Northern Hemisphere: Greenwich, Oxford, Paris, Bordeaux, Toulouse, Potsdam, Helsingfors, Rome, Catania, Algiers.

For the Southern Hemisphere: San Fernando, Tacubaya, Santiago de Chile, Cordoba, Cape of Good Hope, Perth (West Australia), Sydney, Melbourne.

The work connected with the ultimate completion of the catalogue and especially the reproduction of the star maps requires considerable expenditure. Each country has to make its own arrangements, which in the British Empire usually means that each body concerned has to pay its own expenses. There was, however, in this case, some official help. The Astronomer Royal obtained a contribution of £5,000 from the Government for the reproduction of charts, and in the case of the Cape of Good Hope the necessary expenses have been met from imperial funds. Professor Turner, of Oxford, has obtained a grant of £1,000 from the Government grant of the Royal Society, and a further sum of £2,000 for publication from the treasury and the University of Oxford jointly; but the Australian colonies are much hampered by the want of funds, and their work will be delayed in consequence. The four French observatories on the other hand are well supported. Each of them has received a Government contribution of £25,700, making a total of well over £100,000. More than half this goes toward the reproduction of the long-exposure photographs as a series of charts, which, however, have proved to be so costly that they will probably never be completed. Indeed, if completed, their utility may to some extent be impaired by the difficulty of storing them in an accessible manner. Professor Turner calculates that the series of maps will form a pile of papers 30 feet high, weighing about 2 tons.

I now pass on to a few examples of undertakings which are intended to fix standards of measurement, or to establish a general agreement on matters in which uniformity is desirable. The foremost place in this division must be given to the Bureau International des Poids et Mesures, established in the year 1873, at Sèvres, near Paris. This bureau was the outcome of an international commission constituted in 1869, which had for its object the scientific construction of a series of international metric standards. By a convention,

entered into by the different countries at a diplomatic conference held at Paris in March and April, 1875, means were created for carrying out the work of verifying standards under a new international metric committee, and for the purpose of enabling the committee to execute their duties effectually, as well as of securing the future custody and preservation of new metric prototypes and instruments, the Permanent Metric Bureau was founded. The original cost of the bureau was £20,000, and the annual budget was fixed at £3,000 for the period during which the prototypes were being prepared, after which time it was expected that the expenditure could be reduced to £2,000. In 1901, however, it reached £4,000, the maximum to which by the terms of the convention the annual budget could be raised. Great Britain did not join the convention until 1884, when it declared its adhesion. A first payment of £1,787 was made as entrance fee, and the annual contribution now ranges between £200 and £300. Major MacMahon, to whom I owe the above details, is at present the British representative on the international committee.

The work carried out at Sevres is not confined to the reproduction of metric standards, but measurements of precision in various directions have been made with conspicuous success. Scientific thermometry owes much to the international bureau, and in some respects it may be said that exact thermometry was created there. Professor Michelson's work, in which the length of the meter was compared directly with the length of a wave of red light, is another classical investigation carried on in the laboratories of the international bureau. More recently Mr. Guillaume examined the physical properties of alloys, notably those of nickel steel, and proved the possibility of manufacturing a material which shows no sensible expansion with rise of temperature. The importance of metallic rods the length of which does not depend on temperature is obvious, provided they prove to be of sufficient permanence.

It would lead me too far if I were to give an account of the conference and conventions which have led to a general agreement on the standards of electric measurements, but it is a satisfaction to know that these standards are essentially those proposed and first constructed by the British Association. The old British Association ohm no doubt was found to be wrong by more than 1 per cent, but it has remained the prototype of the present international unit, and in principle the old ohm, volt, and unit of current stand as they were given to us by the original committee.[a]

[a] The original committee was appointed in 1861 and consisted of Profs. A. Williamson, C. Wheatstone, W. Thomson (Lord Kelvin), W. H. Miller, Dr. A. Matthiessen, and Mr. F. Jenkins. In the following year Messrs. C. Varley, Balfour Stewart, C. W. (Sir Charles) Siemens, Prof. Clerk Maxwell, Doctor Joule, Doctor Esselbach, and Sir Charles Bright were added to the committee.

While in the case of scientific units complete agreement is absolutely essential, uniformity is desirable in other cases. There are matters of nomenclature in which confusion has arisen purely from want of general agreement. Thus the recent great improvement in the optical power of telescopes has led to the discovery of many details on the surface of the moon. Small craters or other distinctive features named by one observer were not correctly identified by another, so that at the present time the same name is applied to quite different things by different observers. It is quite clear that an international agreement in lunar nomenclature is called for.

There are other deficiencies of uniformity which perhaps appear trivial, but which yet lead to the waste of a good deal of time. Such, for instance, is the position of the index in scientific books. The index is placed sometimes at the beginning, sometimes at the end, and sometimes neither at the beginning nor at the end. Some books have no index, some have two—one for the subject-matter and one for names of authors. The loss of time which arises from one's ignorance as to where to look for the index can not be estimated simply by what is spent on the search, but must include the time necessary to regain the placidity of thought which is essential to scientific work.

We must now turn to the more serious aspect of those international associations which aim directly at an advance of knowledge. Mathematicians have drawn interesting conclusions from the contemplation of ideal beings who are confined to live on the surface and have no knowledge of anything that goes on outside the surface. Our Euclidean geometry would be unknown to them, and spiritualistic tricks could be performed by anyone possessing even to a minute extent the power of controlling a third dimension. It is, I think, worth while investigating the extent of the direct knowledge of a third dimension, which makes us so infinitely superior to the two-dimensional beings. We are able no doubt, through our eyes, to penetrate the depths of space, but we should be unable to interpret the impressions of our sight if we had not some tangible knowledge of three dimensions and had not learned to bring the sense of sight and the sense of touch into harmony. But our sense of touch is confined to a very small distance from the ground on which we stand, and, independently of artificial means of raising ourselves above the surface of the earth, a layer 6 or 7 feet thick represents the extent of our three-dimensional knowledge. Compared with the radius of the earth the thickness of such a layer is small enough, for it would represent only the thickness of a sheet of paper on a sphere having a radius of 250 meters. Compared with the solar system, and even more so with stellar distance, a thickness of 7 feet seems infinitesimal; yet the infinitesimal is essentially different from the zero, and even were our bodies much smaller than they are we should continue to

have the power to interpret three dimensions. These considerations show how important it is for us to increase our knowledge of the earth itself and to extend it as far as possible to the depth below our feet and the height above our heads.

In passing from the arbitrary units to which we refer our terrestrial measurements of length, to the scale on which we measure the dimensions of the solar system, and from them to stellar distances, the magnitude of the earth's radius or circumference forms an all-important immediate quantity. One of the first acts of the French Academy of Sciences, founded in 1666, consisted in organizing the work of accurately measuring the dimensions of the earth, and this at once enabled Newton to confirm his celebrated theory of universal gravitation. As improvements in the methods of measuring kept pace with the work actually accomplished, our knowledge steadily increased, but we are still improving on it. New problems have arisen requiring more minute study, and the measurement of the shape and size of the earth still remain a question of the first importance. The actual surveys and triangulation required for the purpose are of necessity left to the initiative of individual States or to the combination of the States primarily concerned, but the general discussion of results, as far as they apply to the earth as a whole, is entrusted to an international geodetic association, which at present consists of twenty-one States. These, together with their annual contributions to the general fund, are entered in the following table:

Belgium	£80	Austria	£300
Denmark	40	Portugal	80
Germany	300	Roumania	80
France	300	Russia	300
Greece	40	Sweden	40
Great Britain	300	Switzerland	40
Italy	300	Servia	40
Japan	300	Spain	150
Mexico	150	Hungary	150
The colonies of the Netherlands	40	United States	300
Norway	40		

The central bureau of this association is attached to the Royal Geodetic Institute of Potsdam, which is under the distinguished direction of Professor Helmert, who acts as secretary to the association.

The question of measuring the size of the earth depends to a great extent on the measurement of arcs of meridian. As long as we were confined to Europe for the measurements of these arcs they remained necessarily short, but larger portions of our globe have become accessible to the theodolite, and there is especially one arc which is distinguished by the fact that it is the longest possible which can be traced along the land covering the earth's surface. It runs about 30°

east of Greenwich, and a large portion of it passes through Africa. Owing to the great energy and enterprise of Sir David Gill, the work of measuring this arc is well in hand, though at the present moment want of funds threatens to endanger its completion. The Egyptian survey entrusted to Captain Lyons will no doubt receive continued support, and by an arrangement entered into between representatives of the German Government and Sir David Gill at a conference held in Berlin in 1896 Germany undertook to carry out the triangulation through her territory in southwest Africa. I understand this work has been done and the triangulation of the Transvaal and the Orange River Colony is also complete. There is still a gap in the southern part of Rhodesia, but there is every hope that this will soon be bridged over. The British South African Company have spent £36,000 on the work and thus have very materially assisted an important enterprise. When the African arc is complete it will be connected with the Russian and Roumanian arcs, so as to form a continuous chain of 105° extending from 70° north to 35° south latitude. I have to point out, however, that in the opinion of those best able to judge, the completion of the South African arc is not the only undertaking to which this country is called upon to pay attention. The triangulation of our own island, excellent as it was when first made, has fallen below the accuracy required in modern geodetic work. Until our fundamental triangulation has been repeated the sums which at present are being spent on the detailed survey might find a better use.

The main result of the work has been that so far as present measurements allow us to judge, the surface of the ocean can be well represented by a surface of revolution, and it is not necessary to assume a more complicated shape. The mean radius of the earth is determined to about 100 meters, which means a possibility of doubt amounting to about one part in 60,000.

Geodetic work is, however, not confined to measurements of length, for important information may be derived from an exact knowledge of the acceleration of gravity over its surface. The introduction of the pendulum of short length intended for relative and not for absolute measurement has greatly facilitated this work, and it is hoped that these pendulum observations may be carried out over still more extended regions. India is setting a good example. It has measured two arcs of meridian, and the gravitational work carried out by Captain Burrard and recently published by the Royal Society is of primary importance. But, otherwise, British Colonies require encouragement to do more. I am assured that measurements of the gravitational constant in Canada would be of the greatest importance.

The bearing of such work on our knowledge of the earth may perhaps be illustrated by one example. It has often been a matter of

wonder how mountain chains such as the Himalayas could rest on the lower strata of the earth without crushing them and forcing them in by the pure power of their weight, and the most plausible theory to account for this was found in the idea first suggested by Pratt that the mountain chains must not be compared with a large weight resting on an understructure, but rather with a lighter body partially immersed in a heavier one. Mountains, according to this theory, float in the body of the earth very much like icebergs float in water. The truth of this theory can only be tested by accurate measurement of the gravitational force from which information may be derived on the distribution of density in the earth's strata near the surface. On the whole, the measurements so far available have confirmed Pratt's hypothesis.

More recently another problem has occupied the attention of the International Geodetic Association, and owing to its immediate interest has absorbed the greater portion of its funds. The astronomical world was surprised by the announcement of Professor Chandler that he was able to demonstrate from existing observations that the earth's pole describes a closed curve, taking about fourteen months to complate a revolution. The possibility of a periodic shift of the earth's axis was foreseen by Euler, who calculated the time of revolution to be ten months, but observations did not show a sensible period of that duration. No one apparently before Chandler tried to see whether another period beyond a small annual one existed. The discrepancy between the calculated ten and the observed fourteen months was cleared up by Professor Newcomb, who pointed out that Euler's calculation was based on the supposition that the earth is an absolutely rigid body. Any yielding would increase the length of the period; in fact, the earth must be more rigid than steel in order that the period should be as short as fourteen months. This shows how indirect information on the physical properties of the earth may be obtained sometimes in an unexpected manner, the periodic revolution of the pole leading to an estimate of the average rigidity of the interior of the earth. The total displacement of the pole of the earth from its average position is small, never amounting to more than 8 meters. The accuracy with which that displacement can be measured is a testimony to the excellence of our astronomical observations. It is a type of work in which cooperation is absolutely necessary. The subject has received additional interest through the suggestion made by Professor Milne, in his recent Bakerian lecture, that seismic disturbances may be caused by the changes in the position of the earth's axis. Considering that the distortions in the earth are sufficient to increase the periodic revolution of the pole from ten to fourteen months, this suggestion is well worth investigation, and the £300 per annum spent by this country in support of the work of the geodetic

association will be well employed if it allows the vagaries of our pole to be more closely studied and all the dimensional quantities of the surface of the earth to become more accurately known.

The contributions received by the central bureau of this association from the participating States amount to about £3,000, and there is a balance which at the end of 1904 amounted to over £5,000. The expenditure during 1905 was nearly £5,000, reducing the balance by £2,000. The principal items of the expenditure were formed by contributions toward the maintenance of six stations in the Northern and two stations in the Southern Hemisphere for carrying out the observations relating to the changes of the position of the earth's axis. The whole cost of this service is about £4,450. The honorarium of the secretary is £250, which, together with the cost of printing, postage, and a small item for grants toward special scientific work, makes up the expenditure. No charges are made for office expenses, which are defrayed by the Prussian Government.

The geodetic work indirectly gives us valuable, though only partial, information on the interior of the earth, but it confines itself in the main to the surface of the globe; the investigation of the atmosphere carries us beyond.

In an address delivered to the British Association at its Belfast meeting, in 1902, I expressed the opinion that meteorology might be advanced more rapidly if all routine observations were stopped for a period of five years, the energy of observers being concentrated on the discussion of the results already obtained. I am glad to say that meteorologists have taken seriously a remark the echoes of which still reach me from distant parts of the earth. They disagree with me, but their disagreement is of the apologetic kind. I do not wish to retract or to weaken my previous statement, but merely now qualify it to the extent that it is only to be applied to two-dimensional meteorology. There is a three-dimensional meteorology as far removed from the one that confines itself to the surface of the eath as three-dimensional space is from a flat area. Three-dimensional meteorology is a new science, which at present requires the establishment of new facts before their discussion can properly begin. The extension of our range of observations by kites and balloons is of comparatively recent origin. Mr. Archibald in this country was one of the pioneers of meteorological investigation by means of instruments attached to kites. In the United States Mr. Rotch, having established a separate observatory, succeeded in convincing scientific men of the great value of the results which could be obtained. Mr. L. Teisserenc de Bort, who established and maintained an observatory for dynamic meteorology at Trappes, near Paris, rendered similar services with regard to "pilot" or manned balloons carrying autographical instruments. The aeronautical department of the Royal

Prussian Meteorological Institute, with Doctor Assmann at its head, under the direction of Professor von Bezold, also made a number of important contributions in the early stages of the work. Professor Hergesell, of Strasburg, similarly made numerous experiments; and chiefly through the efforts of those whose names have been mentioned, and more especially Professor Hergesell, an international agreement has been secured by means of which kite and balloon ascents are made in several countries on the first Thursday in each month and on three consecutive days during two months of the year. A large station for aeronautical work was recently established at Lindenberg, near Berlin, where kites or balloons are sent up daily for the purpose of securing meteorological records. The greatest height yet reached was during the ascent of the 25th of November, 1905, when by means of several kites sent one after another on the same wire the upper one rose to an altitude of 6,430 meters, almost exactly 4 miles. Owing to want of funds this country could until recently only participate in this work through the individual efforts of Mr. Dines, who received, however, some assistance from the British Association and the Royal Meteorological Society.

The reconstruction of the meteorological office has made it possible now for Mr. Dines's work to be continued as part of the rgular work of the office, and further stations are being established. Mr. Cave carries out regular ascents at his own expense at Ditcham Park, and through the cooperation of the Royal Meteorological Society and the University of Manchester, assisted by a contribution for apparatus from the Royal Society government grant fund, a regular kite station is being established on the Derbyshire moors.

The international committee which collates the observations is a commission appointed by a union voluntarily formed between the directors of meteorological observatories and institutes of countries in which regular observations are taken. The meeting of directors discusses schemes of observations and encourages uniformity.

If I mention a few of the difficulties which stand in the way of a homogeneous system extending over Europe, I do it in the hope that it may perhaps ultimately assist in removing some of them. It is obviously desirable that the charts, which are intended to show the distribution of pressure and temperature, should be derived from observations made at the same hour. Germany observes at 8 o'clock of Central European time, and France observes simultaneously (or nearly so) by choosing 7 o'clock Paris time for its readings. We observe at 8 o'clock Greenwich time, which is an hour later. It is the great desire of continental meteorologists that our standard hour should be 7 o'clock, and what prevents it from being so? Chiefly and absolutely the additional cost which the post-office must claim for the transmission of telegrams; because messages transmitted

before 8 o'clock are subject to an additional charge of 1 shilling which may be claimed by the postmaster, the claim being possibly increase to 2 shillings when the postmaster and telegraphist are different persons. This is prohibitive, but it does not exhaust the inconvenience of the additional charge. For the purpose of weather forecasting it is clearly necessary that telegrams should be received as early as possible by the meteorological office. But the 8 o'clock rule delays telegrams from some Irish stations, because 8 o'clock by Dublin time is 8.25 by Greenwich time, and therefore Irish telegrams may have to wait until nearly half past 8 if they are to be transmitted without extra charge.

While the international organization of meteorology is well on its way, though difficulties such as those I have mentioned may temporarily retard it, another question not altogether disconnected with it has been raised by Sir John Eliot. This is the establishment of an institution devoted to the collective study of meteorological problems affecting all parts of the British Dominions. It is true, not only in this but also in other matters, that in order to take our proper position in international work it is necessary that we should set our own house in order, and we must give Sir John Eliot's proposals our hearty support. If I do not enter further into this question, it is because I am now dealing more especially with problems which go beyond the limits of the Empire. I assume the existence of a national organization, but lay stress on the insufficiency of this limitation.

The importance of the subject, however, may be my justification, if I direct attention for a moment to the meteorological question as it presents itself in India. We all know and realize the vital importance of the rainy season, and the benefit which the native population would derive if it were possible to predict, even if only imperfectly, the setting in of the monsoon. It appears that Doctor Walker, the present director of observatories in India, recently obtained very encouraging results in this respect. According to his investigations, a forecast of the monsoon may be derived from a knowledge of the weather during preceding months in different parts of the world. Thus a heavy rainfall in Zanzibar in May is followed by a weak monsoon, while a pressure deficiency in Siberia during the month of March indicates a probable deficiency of rain in India during the following August. I need not insist on the importance of these results, which at present are purely empirical and require further confirmation, but it is quite clear that for the successful prosecution of these inquiries political boundaries must be disregarded and a system of intercommunication organized between the countries chiefly concerned. Doctor Walker informs me that he has successfully arranged for telegraphic reports to be sent to him at the beginning of June from six different stations in Siberia. It is hoped that this coopera-

tion, which was unavoidably discontinued during the late war, may now be reestablished.

The course of international organizations does not always run smoothly. The efforts made toward cooperation in earthquake records have unfortunately led to differences of opinion, which have hitherto prevented a truly international system being formed: and if I give a short historical account of the circumstances which have led up to these differences, it is only in the hope that this may help to remove them. The scientific investigation of earthquakes may be said to have begun when British professors of physics, engineering, and geology were appointed at the Imperial College of Engineering in Tokyo. Some of them on returning home succeeded in interesting the British Association in the subject. Ever since 1880 that association has been an active supporter of seismic investigations. The much disturbed region of the Japanese islands was naturally the first to be studied, but in 1895 Professor Milne, as one of the secretaries of the committee, issued a circular calling attention to the desirability of observing waves which have traveled great distances, and some months later Dr. E. v. Rebeur-Paschwitz, of Strasburg, drew up suggestions for the establishment of an international system of earthquake stations. To this scheme Professor Milne and other members of the British Association committee gave their approval. The cooperation which thus seemed so happily inaugurated was broken by the unfortunate death of its originator. Circumstances then arose which compelled the British Association committee to go its own way. Under its direction a system was established which now includes about forty stations distributed all over the world. But the needs of different countries are not, and were not, meant to be satisfied by this organization.

There is always a certain number of earthquakes having purely local importance and requiring discussion from a purely local point of view. For the purpose of such discussion relating to the disturbances which chiefly affect central Europe, the union (so-called kartell) of the academies of Vienna, Munich, Leipzig, and Göttingen formed a committee and did excellent work. In the meantime Professor Gerland, who had succeeded Doctor Rebeur-Paschwitz at Strasburg, had personally invited a number of friends interested in the subject to a conference at Strasburg, with the object of forming an international association. This was followed in 1903 by a formal conference called by the German Government, at which Great Britain was represented by Sir George Darwin and Professor Milne. This conference drew up a scheme for an international association, and a large number of countries, including Russia and Japan, joined. Strasburg was selected as the seat of the central bureau. The matter came up for discussion at the meeting of the International Asso-

ciation of Academies, which was held in London in 1904, and a committee was appointed for the purpose of suggesting such modifications in the constitution of the seismic organization as might bring it into harmony with the views of the associated academies. This committee, over which I had the honor to preside, met at Frankfort and recommended a number of important changes, which were unanimously accepted by the second seismic conference, held last summer in Berlin. In consequence of this acceptance, it appears that Italy and the United States joined the seismic association, while England declared its willingness to join under certain conditions, of which the simultaneous adhesion of France was one. The following summary of the States which have joined and their population is copied from the official report of the last meeting at Berlin:

Country.	Population.	Contribution.	Country.	Population.	Contribution.
German Empire	60,000,000	£160	Italy	33,000,000	£160
Belgium	7,000,000	40	Mexico	13,600,000	80
Bulgaria	3,700,000	20	Norway	2,300,000	20
Chile	3,000,000	20	The colonies of the Netherlands	5,500,000	40
Kongo State	19,000,000	80	Portugal	5,400,000	40
Spain	19,000,000	80	Roumania	6,300,000	40
United States	76,000,000	160	Russia	129,000,000	160
Greece	2,500,000	20	Switzerland	3,300,000	20
Hungary	19,250,000	80			
Japan	48,000,000	160			

It was decided at the Berlin meeting that Professor Kövesligethy, of Budapest, should be secretary and Professor Palazzo, of Rome, the vice-president of the International Seismic Association. Professor Gerland had already previously been designated as director of the central bureau. The office of president of the association was left vacant until the final decision of Great Britain as to its adhesion had been settled. There the matter stands for the present.

The disastrous results of recent earthquakes and volcanic eruptions have directed increased attention to the subject. Its thorough investigation is indeed likely to yield important information on the interior constituton of the earth. A hearty cooperation to obtain and circulate the material for a detailed discussion can not fail to bear fruit, and even though there may be legitimate grounds for dissatisfaction at the manner in which a particular scheme has been organized, I must express my own opinion that at the present moment the permanent interests of this country would be best secured by our joining the association and helping to direct its work in a manner which would assist rather than hamper the present organization of the British Association.

I do not like to conclude without mentioning a newly established organization, which has its central bureau in my own laboratory at the University of Manchester. This is a union for the observation

of solar phenomena. Called into being chiefly by the energy of Professor Hale, this association is perhaps unique in two respects. It aims more directly at conducting research work than is the case with other unions, and in so far may run the danger of hampering private efforts. This danger has, I believe, been well guarded against by the constitution adopted at the first meeting of the conference, held last September at Oxford. The second peculiarity referred to is that it works a central bureau, a computing bureau (under the direction of Professor Turner), and is going to publish transactions without any funds beyond those doled out to it by charity. Its vitality will, I hope, help it to overcome its initial troubles. Its ambitious programme includes a definite agreement on the standard of wave length and investigations on the permanence or variability of solar radiation.

This latter question is of considerable interest to meteorologists, and comes, therefore, within the purview of the directors of meteorological observatories, who have also, under the presidency of Sir Norman Lockyer, established a commission charged with its discussion. An arrangement has been made securing cooperation between the two bodies, the Solar Union leaving out of its programme the difficult question of the relationship between sun-spot variability and meteorological phenomena.

Although an unnecessary overlapping of two separate enterprises has in this instance been avoided, such overlapping constitutes a certain danger for the future, as the problems of geo-physics—for the investigation of which international associations are specially marked out—are so intimately connected with each other that a homogeneous treatment would seem to require a central body supervising to some extent the separate associations. Such a central body may be found in the International Association of Academies, which promises to play so important a part in scientific history that a short account of its early history may be of interest. The kartell of some of the German academies and that of Vienna has already been referred to. In discussing the utility of its deliberations Prof. Felix Klein, of Göttingen, first mentioned to me the idea that an association of a similar nature would be likely to prove of still greater value if formed between the scientific and literary academies all over the world. In consequence of this conversation I tried to interest the Royal Society in the subject, and in order to obtain further information Professor Armstrong and myself attended privately, though with the knowledge and consent of the council of the Royal Society, the meeting of the kartell which was held at Leipzig in the year 1897. In the following year the two secretaries of the Royal Society, Sir Michael Foster and Sir Arthur Rücker, together with Professor Armstrong and myself, attended the kartell which then met at Göttingen.

The secretaries were impressed by the great possibilities of the scheme, and the council took the initiative and approached the academies of Paris and St. Petersburg, which both returned favorable answers.

In consequence of the correspondence between these learned societies, the Royal Academy of Berlin, in conjunction with the Royal Society of London, issued invitations for a general conference to be held at Wiesbaden on the 9th and 10th of October, in the year 1899.

The following were represented at this meeting, at which the statutes of the new association were agreed upon: The Royal Prussian Academy of Sciences, of Berlin; the Royal Academy of Sciences, of Göttingen; the Saxon Academy of Sciences, of Leipzig; the Royal Society of London; the Royal Bavarian Academy of Science, of Munich; the Academy of Sciences of Paris; the Imperial Academy of Science, of St. Petersburg; the National Academy of Science, of Washington; the Imperial Academy of Sciences, of Vienna.

The unanimity of the meeting may be judged from the fact that a working constitution, which subsequent experience proved to be eminently effective, was finally arrived at on the second day. Many distinguished men took part in the discussions; amongst them Prof. Simon Newcomb and the late Professor Virchow may be specially mentioned.

Although the Berlin Academy had never joined the German kartell, the first idea of a wider association seems to be due to a distinguished member of that body, the historian Mommsen, who, though of advanced age, was able to be present at the first regular meeting of the association, which was held at Paris on April 16–20, 1901. In addition to the societies which took part in its foundation, the following form part of the association and were represented at Paris: The Royal Academy of Sciences, of Amsterdam; the Royal Belgium Academy of Sciences, Arts, and Letters; the Hungarian Academy of Sciences; the Academy of Sciences of Christiania; the Academy of Sciences of Copenhagen; the Academy "des Inscriptions et Belles-Lettres" of the Institut de France; the Academy of "Sciences, morales, et politiques" of the Institut de France; the Royal Society "dei Lincei," of Rome; the Royal Swedish Academy of Sciences.

This meeting is not likely to pass out of the memory of those who took part in it. Its importance was enhanced by the social functions which were held in connection with it, and which included a luncheon given by President Loubet, at the Elysée, a banquet given by the conseil municipal, and a special performance at the Théâtre Français. The subsequent triennial meeting of the academy, which was held in 1904, passed off not less brilliantly. The representatives of the

learned societies were received by Their Majesties at Windsor, and the lord mayor invited them to dinner at the Mansion House. Social engagements, though welcome as marking the importance of the occasion, are not allowed to interfere with the very substantial work which is being done at these meetings. The list of subjects included in the discussion of the London assembly gives an idea of the activity of the association, which does not stop at the conclusion of the meetings, but is kept alive by the work of its members. A permanent committee was charged with the investigation of the functions of the brain, and others were appointed to deal with questions of atmospheric electricity and of the measurement of magnetic elements at sea. An important proposal to carry out an exact magnetic survey along a complete circle of latitude is under discussion. The section of letters dealt with the mutual arrangements between libraries regarding the interchange of manuscripts, approved the intended edition of the Mahabharata, and considered a proposal to construct a new Thesaurus of ancient Greek. The association also took cognizance of and received reports on independent international undertakings, such as the catalogue of scientific literature, the geodetic association, and the geological congress.

The association meets every three years. To these meetings each constituent academy may send as many delegates as may be found convenient. For the discussion of special questions the assembly divides itself into a scientific section and a literary section.

In each of these sections, as well as in the plenary meetings comprising both sections, each academy has only one vote. At each triennial assembly the next meeting place is chosen. In the intervals between the meetings the affairs of the association are placed in the hands of a council on which each academy is represented by two members or one, according as it comprises both a literary and scientific section or only one of them. The resolutions passed by the association are not binding on the constituent academies, who maintain their liberty of adopting or rejecting them.

The association of academies suffers unavoidably from a certain want of homogeneity, owing to differences in the constitution of its component bodies. Most continental academies contain both literary and scientific sections, and at the organizing meeting held at Wiesbaden marked attention was drawn to the fact that there was no body in England that could be considered as representative of literary studies. If matters had been left as they stood then, this country would have been altogether unrepresentative as regards half the activity of the association. Efforts were made, in consequence, to take a more liberal view of the branches of knowledge coming within the range of the Royal Society and to include literary subjects.

Very unfortunately, in my opinion, these efforts failed, and a charter was granted to the British Academy, which has now been included as a separate body among the list of academies forming part of the association. While in this respect we have been at a certain disadvantage, the constitution of the Royal Society has the great advantage of being truly representative of the Empire. In France, on the other hand, no one can belong to the Academy of Sciences who is not domiciled in Paris. Similarly, although Germany possesses four royal academies (Berlin, Göttingen, Leipzig, Munich), each of them is confined as regards ordinary members to its own locality; so that a professor of the universities of Bonn or Heidelberg, however eminent he may be, could not become a member of any of these academies. Neither in France nor in Germany can the academy therefore be called truly representative. The disadvantages which may arise from this defect have been minimized by adopting a rule that the international association of academies may appoint committees for the discussion of special questions, and that members of these committees need not be members of any of the constituent academies. This to a large degree obviates what would otherwise be a considerable difficulty. Nevertheless I believe that the circumstances to which I have drawn attention form the only impediment in the way of handing over to the association of academies the ultimate control of every new international undertaking and even the charge of some of those already established. It is highly desirable that we should work toward this end. An energetic enthusiast may easily start a new enterprise, and governments are appealed to from different sides for help and support. There ought to be some authoritative body to whom the governments could apply for advice. Overlapping and waste would be thus avoided.

It is not my desire to disguise the difficulties which have sometimes been encountered in providing for joint undertakings on a large scale. Whether national or international, combined work between men of different temperaments always requires some suppression of personality. Even stronger feelings may be involved when a central office or bureau has to be selected which specially distinguishes one locality. The advantage gained by the locality is often one of appearance rather than of reality, for these central offices should be the servants rather than the masters of the undertaking. In order to prevent national feeling being aroused by any preference given to one nation, it has been customary to select a president belonging to a different country from that of the director of the central bureau. There are also a vice-president and a secretary—all belonging to different nations. It is thought that such a distribution of office may assist in preserving harmony. I believe that this is the case, but sometimes at

the risk of impaired efficiency. It can not be denied, however, that the seat of the central office of an important undertaking confers a certain dignity, and it is quite natural that a country should feel some pride in the distinction.

England as a whole has not done so badly. We should not forget that in a great portion of the world all clocks strike the same minutes and seconds. Before long all civilized countries (except Ireland) will have adopted the Greenwich meridian for their standard of time, and we may rightly therefore call Greenwich the central bureau of universal time. The offices of the international catalogue and both the central and computing bureaus of the solar union are situated in this country, and if we have secured an even larger share of the onerous but honorable duties incumbent on such offices the fault is our own. The questions which at the present moment more especially require combined treatment are those of geo-physics, a subject for which very inadequate provision has been made in England. Our earthquake observations almost entirely depend on the self-devotion of one man, and the meteorological office, which might reasonably be expected to take charge of certain portions of the work, such as atmospheric electricity, being kept in a state of chronic poverty, must restrict its activity to work of the most pressing necessity. Germany, on the other hand, having a large number of well-equipped stations for geodetic, magnetic, and aeronautic work, naturally reaps the reward when the offices of an international undertaking have to be chosen which shall be attached to flourishing institutions in charge of men possessing the leisure and qualifications for the work.

No serious advance will be made in our own country in this respect until our universities pay more attention to the subject of terrestrial physics. This would involve the establishment by the universities of separate laboratories or institutions, to which their present funds could not be applied. The matter wants consideration in detail and should be carried out according to a homogeneous scheme which would prevent wasteful repetition in different places. But I feel certain that until we have trained up a number of students who possess an adequate knowledge of questions of meteorology, geodetics, terrestrial magnetism, and seismology the position which this country will take in international organization can not be a leading one, though it may be, and, indeed, owing to private efforts, is at the present moment one of which we need not be ashamed.

Finally, I must lay stress on one aspect of the question which I hope may induce us to attach still greater importance to international undertakings. The cooperation of different nations in the joint investigation of the constitution of the terrestrial globe, of the phenomena which take place at its surface, and of the celestial

bodies which shine equally upon all, directs attention to our common interests and exposes the artificial nature of political boundaries. The meetings in common discussion of earnest workers in the fields of knowledge tend to obliterate the superficial distinctions of manner and outward bearing which so often get exaggerated until they are mistaken for deep-seated national characteristics.

I am afraid I have only given a very inadequate account of the serious interests which are already involved in international scientific investigations. But if I may point once more to Indian meteorology and insist on the vital importance of an effective study of the conditions which rule the monsoon, everyone will, I think, realize how impossible it is to separate scientific from national interests. The solution of this particular problem requires an intimate cooperation with Central Asia and Siberia—a cooperation which has been easily secured. I do not wish to exaggerate the civilizing value of scientific investigation, but the great problems of creation link all humanity together, and it may yet come to pass that when diplomacy fails—and it often comes perilously near failure—it will fall to the men of science and learning to preserve the peace of the world.

SAMUEL PIERPONT LANGLEY.[a]

By Cyrus Adler.

Samuel Pierpont Langley, the third secretary of the Smithsonian Institution, astronomer and physicist, famed the world over for epoch-making contributions to our knowledge of the sun and the establishment of the principles of aerial flight, passed away in his seventy-second year, at Aiken, S. C., on the 27th of February, 1906.

Mr. Langley was descended of families which came to Massachusetts in the early part of the seventeenth century, and to a great extent remained in the colony and even in the State itself. In a biography prepared by the late George Brown Goode eleven years ago, it was pointed out that an unusual number of his ancestors were skilled mechanics and artisans, while on the other hand a group of them were of the most intellectual men of early New England—clergymen, schoolmasters, and indeed one of them, Increase Mather, a president of Harvard College and the author of the first American work on astronomy.

His immediate forbears were especially characterized by great physical and intellectual vigor, wide cultivation, and a staunch sense of duty; and if to these distinguishing characteristics of a long line of ancestors there be added mechanical skill, high moral ideals, and a restless, all-consuming pursuit of new truth, in season and out of season, by skillful methods, upon original lines, we have a picture of the intellectual and moral make-up of the man whose life I am now attempting, inadequately, to portray.

He beguiled the tedium of his last illness by beginning the preparation of his memoirs, which I have been permitted to see. They are so fragmentary that they can never be published, but from them I have been able to learn a few incidents of his early life which it is not improper to recite.

He was born on the 22d of August, 1834, in Vernon street, Roxbury, to Samuel Langley and Mary Williams; attended various private schools, and later entered the Boston High School. His educa-

[a] Read before the Philosophical Society of Washington, November 24, 1906. Reprinted from Bulletin of the Society, Vol. XV, pp. 1–26.

tion was of the type then prevalent, and much of his time was devoted to Latin grammar. On the moral side, the two strongest impressions which he recollected of this period were being taught, a horror of debt and, through it, a sense of duty, and these two traits were firmly present to the last.

Yet another fact taken from these very interestingly written pages shows that his father, himself a wholesale merchant in Boston, possessed a telescope with which the small boy watched the building of Bunker Hill monument.

As a child he was an omnivorous reader, had a reflective mind, an interest in art and in foreign lands, and a very strong bent toward mathematics, all of which grew to importance in later life. Not being sent to college his choice of a profession fell upon civil engineering and architecture, which were primarily chosen because they would afford a livelihood and at the same time keep him near to several of the studies that interested him most.

In 1857 he went to the West, and spent the next seven years mainly in Chicago and St. Louis, engaged in the practice of his profession and in business, acquiring a mercantile training and skill as a draftsman which were of high importance in his later scientific and administrative career.

In 1864 he definitely abandoned his profession and returned to New England, spending some time with his brother, John Williams Langley, in building a telescope, and the brothers afterwards had a year or more of European travel, visiting art galleries and observatories, and indeed all scientific institutions. This European journey had another notable influence in familiarizing him with the continental languages, especially French, in which he acquired great proficiency.

Upon his return to Boston the then director of the Harvard College observatory, Prof. Joseph Winlock, invited him to become an assistant in that observatory; and so at the age of 30 without any previous preparation, but with an accurately trained eye and hand and experience in observation, both in his native country and in Europe, at that time by no means usual, he was enabled to realize the dream of his early life and devote himself to scientific pursuits in that department which had most strongly interested him.

His work with Professor Winlock was of brief duration, though even after leaving Cambridge he continued the association with him for some time. The attachment formed then was a strong one, and he bore in grateful remembrance the man who had given him his first opportunity to realize his early ambitions. In after years, when he came to Washington, he chose as one of his principal assistants here a son of Joseph Winlock, William Crawford Winlock, also an astronomer and for a number of years the secretary of this society.

and to the end of his life he held these two men in affectionate memory.

In 1866 he went to the United States Naval Academy at Annapolis, with the title of assistant professor of mathematics, but with the understanding that his duties would lie principally in the reorganization of the small observatory, whose work had been interrupted by the civil war. There he remounted and put into service the instruments and equipped the observatory for practical and scientific work.

His stay at Annapolis, though fruitful in this regard, was a brief one, for at the end of the same year he was called to the Western University of Pennsylvania, where he became professor of astronomy and physics and director of the Allegheny observatory. This position he held for twenty years, and here it was that he carried on scientific labors of such importance and originality as to have won the international scientific reputation and recognition which caused Professor Baird to invite him to the Smithsonian Institution as assistant secretary, and the Regents to elect him later as its chief executive officer.

His early years at Pittsburg were spent largely in securing the proper instrumental equipment for the observatory, which upon his arrival was one only in name. It consisted of "a building in which was mounted an equatorial telescope of 13 inches aperture, bought by the university of a local club of amateur astronomers. Besides this there was no apparatus whatever, not even a clock, and the equatorial itself was without the necessary accessories."

This was before the period of great endowment for astronomical or, indeed, other scientific research in America, and the group of men whose wealth has since enriched Pittsburg and many other places in this country and elsewhere were with a single exception either at the beginnings of their fortunes or without perception of the needs of science. It was imperatively necessary that money be secured for the purchase of apparatus if the Allegheny Observatory were to do proper work and its director have the opportunity of pursuing his own investigations.

Many affairs of ordinary life, but more especially the growth of railroads, demanded that the common clock, upon which every dweller of a civilized land depends, should be correct and that some plan be devised whereby other than solar time should serve over considerable areas.

Tentative efforts in this direction had been made by the Greenwich Observatory, by the Naval Observatory, by Harvard College, at Albany, at Brussels, and at other places, but nowhere systematically nor upon any really practical or useful plan. To the needs of the Allegheny Observatory and the fruitful mind of Mr. Langley we owe the establishment of the time service, and its outgrowth, the stand-

ardization of time in the United States and in other countries, and through its financial returns the instrumental equipment of Allegheny Observatory was rendered possible, and likewise the great discoveries in astrophysics by its director.

At the age of 35, in 1869, Mr. Langley published his first two papers, the very first being a report of two pages on the observation of the total eclipse of August 7, 1869, at Oakland, Ky., and the second, "a proposal * * * for regulating from this observatory the clocks of the Pennsylvania Central and other railroads associated with it."

When we recall the intolerable inconvenience which attached to the changing of time in every 40 or 50 miles of travel, and the empirical method by which clocks and watches were set, resulting in annoyance, confusion, delay, and disappointment, these early labors of Mr. Langley, resulting in our standard time system and in the almost universal regulation of public clocks through electrical signals from observatories, must be counted, if not an important advance in knowledge, a really great contribution to the convenience, comfort, and welfare of mankind.

While these practical efforts to secure a fund for the equipment of the observatory were maturing, Mr. Langley had the opportunity of carrying on astronomical work under other auspices. In 1869 he took charge of a coast survey party to observe the total eclipse of August 7 of that year at Oakland, Ky., resulting in the brief paper above referred to, and in 1870 he accompanied a Government eclipse expedition to Jerez de la Frontera, which was under the general direction of Prof. Joseph Winlock, and included on its staff besides Mr. Langley, Professors Young and Pickering, both of whom have since become among the foremost of American astronomers.

He had meanwhile not lost his interest in the time service, the methods of which he described in an article in the American Journal of Science in 1873, proposing, in addition to transmitting time to railroads, to supply it to watchmakers and jewelers and to cities in general for their public clocks.

Almost from the beginning of his astronomical work he had devoted his attention to the sun, his investigations being chiefly astrophysical in character, and among his earlier observations in this field were his sun-spot studies, carried on about 1873. From that time on until 1880 he was engaged in minute telescopic study and drawing the details of the surface of the sun, and especially of sun spots. Photography had not begun to be used for such purposes, and his skill and accuracy in making drawings of observations of these phenomena were particularly valuable. Indeed, it is declared by astrophysicists that his sun-spot drawings made at Allegheny prior to 1875 are even yet to be regarded as the best recorded

evidence of their structure. I learn from Mr. Abbot, of the astrophysical observatory, that "Prof. G. E. Hale, who has enjoyed the choicest opportunities for examining the sun, both with the 40-inch reflector of the Yerkes observatory and with the horizontal telescope on Mount Wilson, and also during various expeditions to high mountain peaks, says that in the best views of sun spots he has ever had the better they were seen the more nearly have they appeared as shown in Langley's drawings." In spite of this great power of direct personal observation, he was quick to appreciate and to employ the aids which photography lends to this research, though it should be said that the standard illustration of a sun spot which appears in most of the text-books and works on astronomy of the present time is one drawn by Mr. Langley with his own hand at Allegheny in December, 1873. The following statement of his continued work in this field during his Allegheny period was prepared recently for publication in a general encyclopedia, and, having had the advantage of his own revision, it is taken as an authoritative statement of his researches:

About 1875 he began to devote much attention to the measurement of the heat spectra of the sun and other sources of radiation. Convinced after long experience with the thermopile of the futility of attempting to discriminate the effects of narrow portions of the spectrum by means of any heat-measuring apparatus then employed, he sought to devise something more satisfactory, and in 1879 and 1880 was successful in the invention of the bolometer. This instrument has found high favor for a wide range of experimental work, but in his hands it has been used from 1880 to the present time to open up a great new field of investigation in connection with the invisible long wave-length rays proceeding from all heated bodies and to change many of the older ideas concerning them.

The more important of his many researches published during this period were upon the energy spectrum of the sun, the transmission of the earth's atmosphere and the solar constant, the behavior of prisms toward long wave-length radiators, the energy spectra of heated terrestrial bodies, and the energy spectrum of the moon, the moon's heat hitherto having been recognized with difficulty even in gross by the thermopile, but now, by the bolometer, being analyzed in minute detail in a lunar heat spectrum. More recently a comparison of the proportions of luminous and nonluminous heat in the spectra of the sun and artificial light sources with the corresponding proportions of the light and heat in the radiations emitted by the glowworm gave important economical results.

In 1881, previous observations at Allegheny having led him to believe that there was a great and then unappreciated selective absorption both in the sun's and in the earth's atmosphere, which rendered in the latter case Pouillet's methods inapplicable, and which when recognized tended to give a far larger value to the solar constant, he, with the aid of the Government, organized an expedition to the top of Mount Whitney, the loftiest mountain in southwestern California, whose abrupt precipices permitted observations to be made from two neighboring stations, yet with a distance of more than 2 miles of altitude between them. These observations were published by the United States Gov-

ernment in a volume entitled "Professional Papers of the Signal Service, No. XV. Researches on Solar Heat and its Absorption by the Earth's Atmosphere." Perhaps the most important result of the expedition was the entire change in the hitherto accepted value of the solar constant, while incidentally these and others carried on at Allegheny led to the displacement of the old assumption in favor of the present view, namely, that the general absorption is largest as we approach the violet end of the spectrum.

By 1885 the solar spectrum had been followed by him to wave lengths ten times as great as those of the visible spectrum, and radiations from terrestrial sources even farther, thus overthrowing the ideas previously held of a natural limit to the infra-red wave lengths at about 1 μ. His extended bolometric researches on the heat spectrum of the moon led him to fix the maximum lunar temperature at little above 0° C. In his researches on these long wave-length spectra Mr. Langley developed the optical possibilities and determined the constants of rock salt, a substance already employed by Melloni, but whose range of usefulness was now very greatly extended.

But he did not confine himself during this time either to his labors in the observatory or to making their results known to scientific men through contributions to societies and journals. He had a decided opinion of the right of the world to know what scientific men were doing and a remarkable gift of presenting such knowledge to the man of average intelligence. He occasionally delivered lectures in the city of Pittsburg, which were reported for one or another of the Pittsburg papers, and wrote letters to the Pittsburg Gazette when any unusual astronomical phenomenon which might be of public interest presented itself. By 1875 his reputation had grown to such an extent that he was invited to lecture at Stevens Institute, and his papers, which had heretofore been published only in American journals, commenced to appear abroad in English and Italian periodicals and in the Transactions of the Academy of Sciences of the Institute of France; this, be it noted, within five years from the date of his first publication.

The trend of his mind toward the popularization of science may be judged from a paper which appeared in the Popular Science Monthly in 1877, entitled "The first popular scientific treatise," in which he declared that "science is not for the professional student only, but that everyone will take an interest in its results if they are only put before the world in the right way." The treatise was Fontenelle's "Conversations on the plurality of worlds," and the article, while holding strictly to its subject, showed something of that intimate knowledge of French history to which I shall allude later on.

The question of the personal error or personal equation, which has attracted so many astronomers, also had his attention, and he described in a communication to the American Journal of Science in 1877 a machine whereby this personal error could be entirely eliminated.

In 1878 he took charge of a party sent out by the United States to

witness the total eclipse of that year from Pikes Peak, at an elevation of 14,000 feet, and besides the scientific memoirs which resulted therefrom and through which he was able to follow the corona to a hitherto unsuspected distance from the sun he wrote pleasant, chatty letters describing the more personal side of the work of the party.

In the winter of 1878, during the course of a visit to Europe, he spent some time upon Mount Etna, and made observations there which resulted in the production of scientific papers and a very interesting article entitled "Wintering on Etna," which was contributed to the Atlantic Monthly.

In 1881, through the generosity of the citizens of Pittsburg and with the cooperation of the United States Signal Service, he conducted an expedition to Mount Whitney, to which reference has already been made.

Mr. Langley's general reputation shortly after this became greatly enhanced by a series of popular lectures delivered at the Lowell Institute and at the Peabody Institute at Baltimore, afterwards published in the Century Magazine, and later still in the form of a book, which has gone through several editions, under the title of The New Astronomy. These lectures and this work set clearly before educated people the results of his own labors and of others in that branch of astronomy which, dealing not with the questions of longitude and latitude, or the discovery of planets, asteroids, or comets, or the other problems of the older astronomers, had to do with the physics of the heavenly bodies; the study through patient observation and numerous ingenious devices of not the mere existence of the heavenly bodies, but of their constitution.

The spirit in which this work is written can be gleaned from its very brief preface:

"I have written these pages," he says, "not for the professional reader, but with the hope of reaching a part of that educated public on whose support he is so often dependent for the means of extending the boundaries of knowledge.

"It is not generally understood that among us not only the support of the Government, but with scarcely an exception every new private benefaction is devoted to 'the old' astronomy, which is relatively munificently endowed already; while that which I have here called 'the new,' so fruitful in results of interest and importance, struggles almost unaided.

"We are all glad to know that Urania, who was in the beginning but a poor Chaldean shepherdess, has long since become well-to-do, and dwells now in state. It is far less known than it should be that she has a younger sister now among us, bearing every mark of her celestial birth, but all unendowed and portionless. It is for the reader's interest in the latter that this book is a plea."

Of the scientific importance of this book and of the other work of Mr. Langley I am naturally dependent for my opinion upon others, but I may be permitted to say that its literary character is unsurpassed—indeed, probably unequaled—by the scientific work of any

other in America, and deserves to rank among the popular scientific expositions of Darwin, Wallace, Huxley, and Tyndall.

Even prior to this Mr. Langley had been invited to lecture at the Royal Institution of Great Britain; his fame was growing and recognition was coming to him from many sources.

In the autumn of 1886 Professor Baird, after a personal conference with Mr. Langley, wrote him inquiring whether he would enter the service of the Smithsonian Institution as an assistant secretary in charge of foreign and domestic exchanges, including the international service, the library, and the publications, with the understanding that not more than half of his time should be given to the Institution and the remainder could, as Professor Baird said, be employed in "keeping up those original researches at Allegheny University which have already secured for you so much distinction in the scientific world. The Smithsonian Institution does not desire in any way to interrupt the progress of your investigations; on the contrary, it will be most happy to facilitate them as far as lies in its power, with the hope, at some future day, of being able to give, in Washington, facilities equal, or superior, to those that you can have elsewhere." The reply of Mr. Langley, a portion of which I quote, throws an interesting side light upon the character of the man utterly unsuspected by the world at large and known to only a few of his intimates—that is, a strong craving for real society, by which he meant intercourse with people of diverse minds and knowledge, all of whom might give him that intellectual companionship for which he hungered. Mr. Langley, on November 27, 1886, wrote from Allegheny to Professor Baird:

> I am obliged by your official letter of the 22d instant, inviting me to accept the assistant secretaryship of the Smithsonian Institution, and by its kind allusion to those relations of mine to physical science, which have influenced you in making the proposal.
>
> The opportunity for usefulness in that direction is a strong motive to me for acceptance, as I mentioned in the conference to which you refer; but I find from your letter that I did not then make my actual position plain, as I intended to do. To repeat what I then meant to say, I have no wish or ambition to tempt me from giving most of my time to physical investigation—at least now, while I enjoy exceptional facilities for this, together with a freedom which I could not expect in any subordinate position.
>
> My professional life here is, through the kindness of those to whom I owe more than official duty, a very pleasant one, in most respects, nor have I any occasion to leave the work of my predilection to increase my income.
>
> At the same time both my professional and domestic life here are exceptionally isolated, and I have felt the need of some change which would bring with it, along with society, new occupation, if that could be of a kind not wholly dissociated from my accustomed pursuits.

His loneliness in the Allegheny observatory can be well imagined. Pittsburg of that day was largely engaged in adding to the wealth of the State of Pennsylvania, and, indeed, of the entire country, and

this astronomer and physicist, student of art and literature, philosopher and dreamer, was there almost as isolated as though upon the top of a lonely peak. He told me once that he attended the meetings of the medical society of the city of Pittsburg in order that he might have contact with professional and scientific men, and that he walked down and toiled up Observatory hill once a week to spend Sunday evening in a room back of a drug store, in which four or five men would assemble to discuss the great things of the mind and the scientific problems of the day. It was a revelation to me, as I assume it will be to others, to learn from the letter of Mr. Langley quoted above, that it was principally the desire to associate with others of his kind, and not ambition or opportunities for work, which brought him to Washington.

On January 12, 1887, Mr. Langley was appointed assistant secretary of the Smithsonian Institution. In August of the same year Professor Baird died, and in November Mr. Langley was elected Secretary by the Board of Regents. During his brief term as Assistant Secretary he had given much thought to the departments with which he was especially charged, the exchange service, the library, and the publications, and in these important agencies he retained a deep interest. The exchanges he regarded as one of the principal means for carrying out the terms of Smithson's bequest "for the diffusion of knowledge among men," and to the publications he gave an ever-increasing amount of thought, especially those which could be, to use his term, "understanded of the people," developing the Smithsonian Report to such a point that to-day it appeals to every man of ordinary education and intelligence, and is in many places, where books and libraries are inaccessible, the sole and yet the entirely satisfactory means of keeping people abreast of the scientific advancement of the world.

The hope held out in the letter of Professor Baird that some opportunity would be afforded here for the continuance of Mr. Langley's original researches was made good, first through the generosity of the late Jerome H. Kidder and Alexander Graham Bell and later through appropriations by Congress for the establishment of an astrophysical observatory under the direction of the Smithsonian Institution. This observatory, housed in a modest frame structure on the Smithsonian grounds and entailing an annual cost upon the Government of a very inconsiderable sum, made it possible for Mr. Langley not only to continue his researches, but to reach new and even more valuable results than had been obtained heretofore.

It is due to his initiative and energy that the people of this country have the National Zoological Park. He specialized in astronomy, but his interest in nature was not confined to it. He had an eager curiosity about animal life and a great love for natural scenes, and

so it fell to him, the astronomer, to move successfully in the establishing of the park, which, besides having high scientific possibilities for usefulness and instruction, is one of the great pleasure grounds of the people who live in this capital and to those hundreds of thousands of American citizens who annually make a pilgrimage to it.

Shortly after Mr. Langley's accession to the secretaryship, and aside from his work in the establishment of the observatory, he strongly desired to create a new activity for the Smithsonian Institution, and his first choice would have been that of extending its scope in the direction of the fine arts. But the time was not then ripe. He met opposition and foresaw insuperable difficulties, and so he reluctantly abandoned this field and put his persevering energy into the other just mentioned, the establishment of the park. But he always had the feeling that the Smithsonian Institution should act for the nation in the matter of art. He caused to be collected such art objects as belonged to it and were deposited elsewhere, and reimplanted, as it were, the idea of the fine arts in the Institution by setting aside a room in the Smithsonian building which should be devoted to these collections. His death came at a time when the realization of this idea of his was about to have fruition.

He had for many years been in the habit of going annually to Europe, and this personal contact with the scientific men of England and of the Continent and the reputation that his researches had brought to him and to the Institution, and his increased zeal in pushing forward the exchange service, led to a great enhancement of the international reputation of the Institution.

It was my rare good fortune to accompany Mr. Langley upon two of his European trips—first in 1894 and again in 1898. Upon the first occasion I heard him read before the physical and astronomical sections of the British Association for the Advancement of Science a paper describing his work on the infra-red spectrum. The meeting was held at Oxford, and the hall, holding some 250 persons, was crowded. He spoke very simply and without notes, describing the apparatus that he had devised and brought together and the results that had been attained; and so vivid was his statement and so forceful that at the conclusion of his remarks the supposedly stolid Englishmen who composed the audience arose almost in a body and cheered. At a meeting of the physical section on the same occasion he discussed the future of aerial navigation. The session was held under the chairmanship of the late Lord Salisbury, premier of Great Britain, and that year president of the association, and the discussion that followed was participated in by Lord Kelvin, Lord Rayleigh, and Sir Hiram Maxim, none of whom dissented from the views which Mr. Langley expressed.

None regretted more keenly than he that of the many great benefactions which came to American science few, if any, found their way to the funds of the Smithsonian Institution; so that relatively the activities of the Institution proper were not increased in the United States commensurate with the growth of other scientific organizations, though it should be said that after the original foundation the only important addition to the Smithsonian funds, that received from Thomas G. Hodgkins, came during the administration of Mr. Langley.

Among his many notable addresses was that delivered in 1888, as the retiring president of the American Association for the Advancement of Science, under the title of "A history of a doctrine," this doctrine being the views concerning radiant energy. The address is a charming one in every respect—as an historical investigation, as a summing up of results obtained, as a literary document, and as a prophecy. Some of the phrases are worthy of a great philosophic mind. "We have perhaps seen," he declared, "that the history of the progress of this department of science is little else than a chapter in that larger history of human error which is still to be written." And yet there is no pessimistic note in it, for he asks the question, "Shall we say that the knowledge of truth is not advancing?" and he replies to this query, "It is advancing, and never so fast as to-day; but the steps of its advance are set on past errors, and the new truths become such stepping-stones in turn."

To this same time belong other papers of great general interest, notably that on "The observation of sudden phenomena," which will have a certain value even for the physiological psychologist, although designed for the astronomer primarily and containing descriptions of the personal-error machine invented by Mr. Langley; and also another paper on "The cheapest form of light," this study being based upon an examination of the radiation of the firefly, and showing that it is possible to produce light without heat other than the light itself, and that this is actually effected now by nature's processes.

I am brought, however, to another field of scientific work in which Mr. Langley engaged and with which his name has been identified during the past fifteen years, the subject popularly known as flying machines, and which he denominated aerodynamics. Mr. Langley came before the scientific world and the public generally on this subject first in a very brief communication to the Academy of Sciences of the Institute of France, in July, 1890; second, by the publication of an extended memoir in the Smithsonian Contributions to Knowledge, and third, through a brief popular article on the possibility of mechanical flight, in the Century Magazine. I alluded above to one of the group of what would now be called "captains of

industry" in Pittsburg, who had sympathized with Mr. Langley and his work and had aided him in its prosecution. The name of this man, William Thaw, was commemorated in the preface to "Experiments in aerodynamics" in the following phrase: "If there prove to be anything of permanent value in these investigations, I desire that they may be remembered in connection with the name of the late William Thaw, whose generosity provided the principal means for them," though it should be said that Mr. Thaw's aid in this direction was not to be measured alone by money contribution to the experiments, for it meant much at that time that as eminently a practical man as he should have believed in what was then considered a wild idea, and have supported a scientific man in it both by money and by moral encouragement. This memoir, "Experiments in aerodynamics," was at once republished in full in French and attracted widespread attention. Mr. Langley persevered in the study, and in 1893 he issued a second memoir, "The internal work of the wind." This also appeared in English and French, and was designed to prove that aerial flight had an aid, described as the potentiality in the internal work of the wind, which would be of great moment in the practical solution of the problem.

But the painstaking experiments with the whirling table and with other forms of apparatus devised by Mr. Langley for the study of the question of aerial navigation did not content him, and although not himself a mechanical engineer, and with very inferior appliances, he took up the building of a machine driven by a steam engine, which he hoped would practically demonstrate the possibility of mechanical flight. There were innumerable mechanical difficulties in its construction and also in its launching, and, after failures which would have disheartened an ordinary man, success came in the spring of 1896 when a steam-driven aerodome, constructed under Mr. Langley's direction in his own shops, engine and all, actually flew for three-quarters of a mile or more over the Potomac River. This remarkable success had world-wide recognition. It was communicated to learned bodies, was the talk of the newspapers, and in a specially written article in McClure's Magazine Mr. Langley himself described this trial and how he came to enter upon the subject. From his own words we learn that this was a problem with him from childhood days; that he used to lie in a New England pasture and watch the hawks soaring far up in the blue, and sailing for a long time without any motion of their wings, and this question he thought of in mature life and set himself to inquire whether the problem of artificial flight was as hopeless and as absurd as it was thought to be. "Nature," he says, "has solved it, and why not man?" And with this question he described the experiments with the whirling table down to the

actual flight. As was his wont, he discussed the attempts of those who came before him, and in simple language explained the theory upon which mechanical flight would be possible. This article, printed in 1897, closed with the following paragraph:

> I have thus far had only a purely scientific interest in the results of these labors. Perhaps if it could have been foreseen at the outset how much labor there was to be, how much of life would be given to it, and how much care, I might have hesitated to enter upon it at all. And now reward must be looked for, if reward there be, in the knowledge that I have done the best I could in a difficult task, with results which it may be hoped will be useful to others. I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it do not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened.

Immediately after the success of these experiments and shortly before the article was written, Mr. Langley passed through a most depressing period of his official and personal life, and his feelings then were no doubt reflected in its closing words. In the month of September, 1896, his two principal associates in the Smithsonian Institution, George Brown Goode, a distinguished naturalist, who was in charge of the Museum, and William Crawford Winlock, already alluded to, had prematurely passed away, and their loss was a serious blow to Mr. Langley, whose friendships were deep ones. Of both these men he wrote memoirs—in fact, of Mr. Goode two, the longer of which, presented to the National Academy of Sciences, is at once a discriminating and affectionate tribute to a great man and a dear friend.

For the next few years Mr. Langley's time was not so productive; his physical health was good, but the severe strain of his scientific labors and his personal losses tended to a depression of spirits which caused him to shrink from new work. In spite of his almost definitely announced intention no longer to carry on the work in flying machines, he was led in 1898, through circumstances not clearly known, but which had to do to a certain extent with the Spanish-American war, to take up the building of a flying machine large enough to carry a man, this work being undertaken under the Board of Ordnance and Fortification of the United States Army, and with an allotment made by that board for the purpose. He had meanwhile, after a little lapse of time, renewed his astrophysical work, which, through the improvement of the instruments he had invented, produced new and valuable results. The bolometer was brought to a greater degree of refinement than had ever been attained. The researches of the Astrophysical Observatory had progressed to such a point as to justify the publication of a remarkable volume of

annals; and an expedition made by him, to observe the solar eclipse of 1900, at Wadesboro, N. C., was signally successful.

A half dozen or more papers illustrating the various advances made in the study of the spectrum were also issued about this time. The building of the large aërodrome and of models to aid in its construction was rapidly being pushed ahead. Since the successful flight of the first aërodrome in 1896 a further possibility of increased power with comparative lightness had come with the employment of the gas engine, and this was experimented upon with a view to determining its feasibility for the purpose.

In the midst of these labors, either of them enough to engross the thought of an ordinary man, carried along as they were in addition to the management of the Institution and its correspondence and the interviews and the appearances before committees which this work entailed—in the very midst, I say, of these labors there appeared an article, of all places, in the Saint Nicholas Magazine, describing the Children's Room of the Smithsonian prefaced by a letter written by Mr. Langley himself, in which he appears as the attorney for the children and pleads their cause with a grown-up Museum man, and almost at the same time he wrote a curious and interesting paper describing the fire-walk ceremony in Tahiti, where Mr. Langley spent part of the summer of 1901, and where he hoped to find a miracle, but witnessed instead an interesting ceremony, which, almost to his own regret, he was able to explain by natural law.

A brief popular account of the subsequent experiments with the Langley aërodrome was published in 1905, an extended memoir on the subject being yet unpublished, though left in such shape as to render its publication certain. He describes in the briefer paper the attempt made to purchase a suitable engine or to secure its building by contract elsewhere; the acceptance of such a contract by a mechanical engineer, and the failure, after two years, to deliver the engine in accordance with agreement; the consequent necessity of building it at the Institution; the innumerable details of construction that had to be considered, and, finally, the trials, first of the test models, which proved successful. Twice, on the 7th of October, 1903, and again on the 8th of December of the same year, attempts were made to launch the large machine, and in both cases, according to the observation of numerous reliable engineers, members of the Board of Ordnance, and others, it was the launching that proved a failure, and the words of Mr. Langley, in closing this statement, seemed to be justified: "Failure in the aërodrome itself," he declared, "or its engines there has been none; and it is believed that it is at the moment of success, and when the engineering problems have been solved, that a lack of means has prevented a continuance of the work."

There can be no doubt but that this failure to launch the big machine was a serious blow to Mr. Langley. Not so much the failure itself, for he was a philosopher and a scientific man who knew that success came only after repeated defeat. Had it meant unsuccessful experiment in his laboratory or shop it would have daunted him not in the least. It was necessary to make these experiments in the open air before the eyes of the world, while his arrangements with the Board of Ordnance and Fortification rendered it imperative that the details of the construction should not be made public. The newspaper press of the country, misunderstanding his motives and angered possibly at the large expense connected with maintaining special correspondents at an inconvenient place on the Potomac River, united in a chorus of ridicule and attack, which in time made itself felt in the National Legislature. At his years—for he was then nearly 70—the attitude assumed by the public press broke his spirit at this, the first, indeed, the only, defeat in his career.

The lack of means of which he speaks was only a lack of funds from the source from which he thought he was entitled to obtain it. One or more private individuals offered him the opportunity to continue. Several years before he had been offered a considerable sum for this work if he would but place it upon some commercial basis and take out patents on such portions of the machinery as were patentable in order that commercial reward might come to the persons furnishing the money, but he steadfastly refused either to secure a patent or to accept money from private persons. He declared that this work was solely in the interest of the Nation, and if the Nation was not prepared to support it he was not willing to proceed with it. As far as I can learn, he never wavered in his belief that success would result from his work. Aerial navigation was, in his opinion, sure to come, and the very machine which was declared by the public press to have been wrecked beyond hope he had repaired in absolute condition for another trial.

It is a gratification to be able to record that the last paper that he ever read was a series of resolutions adopted by the Aero Club, at New York City, expressing appreciation of his work in behalf of aerial navigation and confidence in the directions which it had taken, and any reader of the current magazines or the daily press can see for himself that, in spite of criticism and ridicule, the principles which he discovered are more and more gaining recognition. The future of aerial navigation lies not in the direction of the balloon, which is being abandoned even by its most ardent votaries, but in that of the aeroplane; and whatever form this may take or whatever modifications may be made as the result of experiment, the laws of aerodynamics will be the laws which Mr. Langley discovered, and the

aeroplane or other form of machine heavier than the air will be based upon the models which he made and which actually flew.

The tributes in recognition of his work are almost too numerous to recite. He received the degree of D. C. L. from Oxford, D. Sc. from Cambridge, and, among numerous others, the degree of LL. D. from the universities of Harvard, Princeton, Michigan, and Wisconsin. He was awarded the Henry Draper medal by the National Academy of Sciences, the Rumford medal by the Royal Society of London, and the Rumford medal by the American Academy of Arts and Sciences, as well as the Janssen medal from the Institute of France, and the medal of the Astronomical Society of France. He was a foreign member of the Royal Society of London, a correspondent of the Institute of France, a fellow of the Royal Astronomical Society of London, member of the Royal Institution of London, member of the Academia dei Lincei, of Rome, of the National Academy of Sciences, and of many others.

Mr. Langley, although a member of very many scientific and other societies, was not a regular attendant at any of them. He systematically avoided holding any office in any society, the only exceptions that I know of being his presidency of the American Association for the Advancement of Science, his acceptance of the vice-presidency for a brief time of the American Philosophical Society, and membership in the council of the National Academy of Sciences. It was not that he failed to recognize the importance of scientific societies, but rather that he felt confident that others could attend to their management, and that his time must be guarded for his official duties and for his scientific work.

Among the many societies to which he belonged he had an especial affection for this philosophical society. He was elected to membership in it in 1887, the year in which he came to Washington, and with hardly any exception read before it the scientific papers that he presented in this city. Many of you will probably remember his various papers on the infra-red spectrum and that on mechanical flight, and I may be permitted to say in passing that no novice ever prepared a paper or lecture more carefully than he did, for while he always spoke with great directness and simplicity and clearness, apparently without effort and usually without notes, his communications were always written carefully in advance, every slide gone over, and an actual rehearsal made, and this method was one that he carried into his scientific work as well. I remember that before going on the eclipse expedition to Wadesboro there was a rehearsal almost daily for a period of nearly three months on both his own part and that of every other person in the party as to the duties which each one would be expected to perform during the very few moments when the phenomenon was observable.

One would naturally suppose that what has gone before at least fully described a single man; indeed, it relates enough to fill the lifetime of two or three men; yet it by no means adequately goes to make the full picture. I have alluded above to his having been an omnivorous reader, but this is too general an expression to give any idea of the extent of his literary cultivation. He knew the German classics, but had, like many men of his generation, an especial fondness for Heinrich Heine. It is not too much to say that he knew everything good in English, though he had some special interests and had become an ardent Borrovian. He personally owned a considerable selection of the original manuscript of George Borrow, and aided in the preparation of the Life of Borrow, by Knapp, visiting him at Oxford and furnishing suggestions and information for this interesting work. The history of England and, even more, the history of France engaged his attention. He was at one period of his life an ardent admirer of Thomas Carlyle, whose personal acquaintance he enjoyed, and it is not impossible that from him he acquired a sort of method of historical reading, for he looked to men rather than to documents of the periods as furnishing the keynotes for the progress of nations. Leonardo da Vinci, and Cromwell, and Frederick the Great, and Louis XIV, and Napoleon, and Lincoln were some of the men about whom he had read everything available to the student, and he had gone deeply into the memoirs of their respective periods, more especially, however, the French memoirs, with which he had an acquaintance that might have been envied by a professional historical student. He was especially interested in the problems of the soul, and studied the metaphysicians and the modern psychologists, and was himself associated with societies for psychical research, and personally engaged in the examination of spirit mediums, though never with satisfaction to this keen observer. He knocked hard and loud at the door which leads to knowledge of the soul, for it seemed to have been one of the necessities of this great mind that it should attempt all the difficult problems which were offered to human observation or curiosity. He loved to talk with men possessed of positive religious views upon their own beliefs, and had a deep interest in a Jesuit, or a Jew, or a Buddhist, or a Mohammedan, or, indeed, any man who thought he had secured the truth and knew the way of life in this world and the world to come. His paper on "The laws of nature" is a very significant contribution from this point of view.

He was probably less understood upon his personal side than any other. When I came here to live in 1892 I remember that Mr. Goode said to me once that Mr. Langley was a very reserved man and a very lonely one, and that though it might be difficult to gain his friendship the effort was well worth the making. I do not know that I did make a conscious effort. In my then position as librarian

I came into official contact with him because of his very great interest in and constant demand for books of every nature. By chance I found that he was a collector of translations of the Arabian Nights and had read all the editions in English and French available. I happened to tell him of my own interest in the subject and the fact that as a student I had read portions of the Arabian Nights in the original. There then began a closer acquaintanceship which, I am proud to say, resulted in a friendship which has been to me one of the most profoundly valuable and touching experiences of my life. He was a very shy man and greatly feared that he might obtrude himself upon others or that an advance that he might make would prove unwelcome. He was also, like some other mathematicians and astronomers, at times very much abstracted and with a painfully bad memory for names, or, rather, an inability to associate faces and names—a difficulty which he told me had nothing to do with his scientific studies, but was inherited and belonged to his father, who was a merchant. This difficulty he attempted to hide as far as possible, producing upon the average man the conviction that he was dealing with a very haughty and distant individual—a deduction which was very far from the truth.

Living here without family ties, coming in his fifty-third year, almost after the period when men make close friendships, his hunger for real friendship and affection was pathetic. Most of the men with whom he came into contact were of another generation, and it was a genuine revelation to see him, as I sometimes did, with a friend of his youth, a man of his own age whom he had known for many years. He was a most rigidly truthful man—not truthful in any ordinary sense, but in that extraordinary Puritan, New England sense, which did not even permit him to subscribe himself as being "very sincerely, yours," if he was not.

I have alluded above to the fact that he himself ascribed his interest in aerial navigation to a childish wonder as to how the great heavy birds which he used to watch in a New England pasture could fly and maintain themselves in the air, and in another place he has told us that his work on the sun also grew out of a childish interest in this great center of our system upon which life on this planet depends. I think that these two ideas of his were not fancies, but that it was a fact that in his case especially the child was father to the man. One of his favorite quotations was the initial stanzas of the poem of Wordsworth:

> Who is the happy warrior? Who is he
> That every man in arms should wish to be?
> It is the generous spirit, who, when brought
> Among the tasks of real life, hath wrought
> Upon the plan that pleased his boyish thought.

But this memorial, inadequate as it may be, must draw to a close. I have been able to faintly trace the lines of a great mind and a great soul, one that left a powerful impress upon the knowledge and thinking of the country in which he was born and the time in which he lived, and his name and his fame are bound to be handed down through all posterity. Yet he valued these labors and the results which sprung from them but little when compared with the affection of his kin and of his friends—affections not many in number nor easily obtained, for he was, as I have said, a shy man; but he gave in full measure his confidence and his love to those whom he called friend.

A long life filled with many perplexities left his soul white. This Nation and the world at large is the richer for the life of this great man.

INDEX.

A.

G.

H.

I.

T.

U.

V.

W.

Y.

Z.

O